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Selective logging causes the decline of large-sized mammals including those in unlogged patches surrounded by logged and agricultural areas

Jamaluddin Jamhuri[a], Liza D. Samantha[a], Sze Ling Tee[a], Norizah Kamarudin[a], Adham Ashton-Butt[b], Akbar Zubaid[c], Alex M. Lechner[d], Badrul Azhar[a,e,*]

[a] Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] School of Biological Sciences, University of Southampton, Southampton SO17 1BJ, United Kingdom
[c] Faculty of Science and Technology, National University of Malaysia, 43600 Bangi, Selangor, Malaysia
[d] School of Environmental and Geographical Sciences, University of Nottingham Malaysia Campus, 43500 Semenyih, Selangor, Malaysia
[e] Biodiversity Unit, Institute of Bioscience, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

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ABSTRACT

Legal and illegal logging is prevalent throughout the tropics, impacting on natural habitat and wildlife. This study aimed to investigate the sensitivity of forest mammals to selective logging in the lowland dipterocarp forests of South-West Peninsular Malaysia and identify the underlying factors that determine species occurrence. A total of 120 camera trap locations were deployed within selectively logged and unlogged forests. We found that unlogged forest had greater wildlife occurrences compared to selectively logged forests, including two endangered mammal species not found in logged forest. Forest vegetation structure characteristics such as the abundance of lianas, large trees, saplings, palms, bamboo and seedlings were associated with mammal species richness. Mammal species richness increased with number of forest trees, particularly those with a DBH of > 45 cm, but this was limited to high altitude forest. Worryingly, we did not detect any large mammalian apex predators such as leopards or tigers in either unlogged or selectively logged forests. The absence of these animals may be the result of poaching, habitat degradation or other pressures; these mammals are expected to be present in intact forests in Peninsular Malaysia. Restoring logged forests and preserving the remaining unlogged lowland dipterocarp forests are critically important to safeguard mammalian biodiversity in the region. Besides that, we recommend that conventional logging practices are replaced with reduced impact logging methods.

1. Introduction

Tropical forests globally are being threatened by logging, fragmentation, and degradation (Edwards et al., 2014; Gaveau et al., 2014; Abood et al., 2015; Barlow et al., 2016). The increase in forest loss and degradation has significant repercussions for climate change mitigation and biodiversity conservation (Margono et al., 2014). Two hundred and forty million hectares of natural forest has been cleared worldwide from 1990 to 2015 for purposes of agricultural expansion and urban development (FAO, 2016). Tropical forest area declined at a rate of 5.5 M ha y^{-1} between 2010 and 2015 (Keenan et al., 2015).

Such drastic changes in forest cover will impact on forest ecosystems and wildlife. Forest conversion to oil palm plantations, a major driver of forest loss in Southeast Asia, has caused significant changes to species compositions and abundances due to the sensitivity of wildlife to landscape modification (Bernard et al., 2014; Fitzherbert et al., 2008). Logging is another major driver of forest loss and degradation in Southeast Asia; in Malaysian Borneo species richness in newly logged areas declined by 11%, but areas that were logged more than a decade ago had the same levels of species richness as in old-growth forest (Brodie et al., 2015). However, for some species such as primate and ungulate species, anthropogenic threats from hunting posed greater risks than logging and were particularly severe for biologically significant fauna such as seed dispersers and herbivores (Brodie et al., 2015).

High demand for timber products has led to high rates of harvesting in Southeast Asia that has consequently contributed to a loss of biodiversity (Sodhi et al., 2004; Yamada et al., 2014). Commercial logging in Southeast Asia, commonly based on selective logging techniques, mainly targets dipterocarp species when the trees reach a particular height. Thus vertebrates relying on these trees are adversely affected (Johns, 1985; Meijaard et al., 2005). However, recent studies have

* Corresponding author at: Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
E-mail address: b_azhar@upm.edu.my (B. Azhar).

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shown that even after logging these forests are still of high conservation value for wildlife, though many species are negatively impacted (Edwards et al., 2011; Gibson et al., 2011; Putz et al., 2012). Selective logging appears to be the potential cause of species extinction of animals in Southeast Asia such as Malayan tiger *Panthera tigris*, Asian sunbear *Helarctos malayanus* and Asian tapir *Tapirus indicus* (Pimm and Raven, 2000; Okuda et al., 2003; Bischoff et al., 2005).

Tropical forest degradation from selective logging can also cause significant changes to species composition and abundances through the creation of secondary forests or logged forests (McMorrow and Talip, 2001). Secondary forest consists of naturally regenerating forest that has experienced a significant loss of the original vegetation, either at a single point in time or over a prolonged period. Secondary forest often differs greatly in forest structure and tree composition compared to comparable primary forests sites (FAO, 2003). Selective logging can modify interactions between species and ecological processes causing a decline in wildlife populations, imbalances in ecosystems and extinction of native species (Cowlishaw et al., 2009; Sasaki and Putz, 2009; Mayor et al., 2015; Magrach et al., 2016; Olsoy et al., 2016). Species richness of invertebrates, amphibians, and mammals decline as logging intensifies, but these effects vary with taxonomic group and continental location (Burivalova et al., 2014). However, selectively logged forests are quite similar to primary forests in terms of the possibility for thermal buffering and ensuing capability to preserve temperature-sensitive species under climate change (Senior et al., 2018).

In Malaysia, where our study takes place, a Reduced Impact Logging (RIL) system has been implemented to reduce the ecological impacts from forestry (Tay, 1999; Bicknell et al., 2014; Nagulendran et al., 2016). In areas where RIL has been used biodiversity effects are noticeably less intense, unlike where conventional methods are applied (Azevedo-Ramos et al., 2006; Bicknell et al., 2014). RIL includes skid trail planning and directional felling techniques to avoid soil damage that can reduce plantation or pasture productivity for decades (Putz et al., 2008) and can reduce adverse impacts on ecosystem functions and services (Edwards et al., 2011; Putz et al., 2012). However, recent studies suggest that the effects of RIL are minimal on non-volant mammals and birds (Azevedo-Ramos et al., 2006; Wunderle et al., 2006) and negligible on other species, but may increase biodiversity for some taxa via the increase in habitat heterogeneity (Castro-Arellano et al., 2007). Nevertheless, Burivalova et al. (2015) suggest that the influences of logging can be lessened through forest management approaches such as increasing the rotation cycle and executing RIL.

The response of forest mammals to selective logging are poorly understood due to their cryptic behaviour and low densities. Hence, this study aimed to understand the long-term effects to forest mammals of selective logging. We did this by quantifying differences in species richness and composition between forty-year old logged forest and unlogged forest. In addition, we assessed key habitat quality characteristics which drive those differences. Our data will provide vital information for forest managers for better post-logging forest wildlife management and conservation in the tropics.

2. Methods

2.1. Study area

Our study area was located in a contiguous forested landscape in the southwest of Peninsular Malaysia, comprising the states of Selangor and Negeri Sembilan (Fig. 1). The study areas were classified into two types: unlogged forest (latitude 2°33′58.95″N and longitude 102°11′56.76″E) and selectively logged forest (latitude 6′6.07″N and longitude 101°52′50.29″E) with an average altitude of 163 to 505 m. The study areas are characterized by lowland dipterocarp forest. Both logged and unlogged forests were physically connected despite these forests being located in different states. Logged areas and oil palm plantations surround the unlogged forest. Timber extraction occurred 40 years ago in the logged forest. The logging in the study areas followed the Selective Management System, developed in the late 1970s (Meijaard et al., 2005). This system allows the extraction of all commercial species with a DBH > 45 cm for non-dipterocarps, and > 50 cm for dipterocarps. The Selective Management System aims to maintain sufficient regeneration potential in the logged forest areas to allow re-harvesting thirty years later, with a minimum of 32 stems of commercial species in the 30–45 cm DBH size class maintained per hectare (Hadi et al., 1987; Appanah, 1998).

2.2. Animal sampling

A systematic sampling design was used. We selected a starting point at least 500 m from forest edge at random and then systematically located succeeding points at set distances (minimum of 500 m apart) from this (Morrison et al., 2008). Camera traps (Bushnell 8MP Trophy Cam HDs with Night Vision) were deployed at 120 locations in the logged and unlogged forests (60 cameras in each forest type) (Fig. 1). The cameras were installed in the forests based on the following considerations and as close to pre-selected points as possible: availability of access routes; presence of visible animal trails; and tree marks by wildlife; footprints and scars (Bernard et al., 2014; Sasidhran et al., 2016).

Each camera was geo-referenced using a Global Positioning System (GPS) (Garmin 78) with a minimum accuracy of 5 m. Cameras were left in the forests for a month without using bait. Nichols and Karanth (2002) recommended that two weeks is the minimum sampling period, but we doubled the time from two weeks to four weeks in order to increase the probability of detecting wildlife present in both study areas. Due to limited number of camera traps, only 25 camera traps were used simultaneously in unlogged and logged forests. We conducted the camera trapping survey in three trapping periods from May 2015 until April 2016. We identified the survey months as either dry (January – February and May – September) or wet (March – April and October – December) and included season in the analysis.

All camera traps were attached to the base of trees approximately 0.5 m above the ground, with the camera lenses facing outwards. When triggered, the camera traps were set to take three images with a one-second interval between them. The passive infrared motion sensor was set to a normal setting, so that it could detect any movement that passed in front of the camera (Bernard et al., 2014; Mohd-Azlan and Sharma, 2003; Sasidhran et al., 2016). The camera comes with a night-vision feature that enables it to function day and night. This method of setting up the camera traps has proved to be effective in studying the occurrence of elusive mammal species in tropical forest in previous studies (Kawanishi and Sunquist, 2004; Azlan et al., 2006; Bernard et al., 2014; Sasidhran et al., 2016).

2.3. Assessment of habitat quality characteristics

We measured ten characteristics of stand-level habitat quality at each camera trap location in the unlogged and logged forests (Table 1). A plot size of 50 m × 20 m (0.01 ha) was established. Characteristics included: i) number of trees with diameter above 45 cm at breast height (DBH), ii) number of trees with DBH below 45 cm, iii) number of bamboo clumps, iv) number of liana species, v) number of palm trees, vi) number of fallen trees, vii) number of saplings (1–5 cm DBH), viii) number of seedlings i.e. woody plants smaller than 1 cm DBH, ix) percentage of light gaps, and x) altitude.

The number of saplings was recorded within a 5 m × 5 m plot, while the number of seedlings was recorded within a 2 m × 2 m plot, both within the 50 m × 20 m plot area. Percentage of light gaps was measured using a digital camera in a near-vertical and skyward direction, at 4 points taken randomly within the 50 m × 20 m plot area. The images captured by the camera were then analysed using MATLAB 7.1 to estimate canopy cover, with a light gap image analysis script created by