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Camera-trapping rates of mammals and birds in a Bornean tropical rainforest under sustainable forest management

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ABSTRACT

To evaluate the effectiveness of sustainable forest management (SFM) for wildlife conservation, we investigated the abundances of medium to large ground-dwelling vertebrates in a forest management unit in Borneo by camera trapping. The forest management unit (FMU), Deramakot Forest Reserve (55,083 ha), has applied SFM for the past 15 years. We established 15 plots in preharvested areas and five plots in postharvested areas over the FMU. Plots in the postharvested areas had been subject to reduced-impact logging from 2 to 13 years ago. We obtained photos of ground-dwelling vertebrates with infrared sensor cameras set at 12 random points in each plot. Based on the numbers of photos taken over 770 camera days in each plot, we calculated the mean trapping rate (MTR) of each species for each plot. Over the 20 plots, we obtained 5444 photos of 39 medium-to-large vertebrates (i.e., mammals, birds, and monitor lizards); these included many elusive and endangered species. Among the 39 species, no species showed a significant difference in MTR between the pre- and postharvested areas. Furthermore, species composition was not significantly different between the pre- and postharvested areas. Our results support the idea that implementation of SFM can be an effective investment in wildlife conservation in tropical rainforests.

1. Introduction

Although tropical rainforests have a high biodiversity (Richards, 1952; Whitmore, 1998), most of the area in the Southeast Asian is used for timber production (Johns, 1997; Dennis et al., 2008). The direct and indirect impacts of logging activity on biodiversity have been widely noted (Burgess, 1971; Heydon and Bulloh, 1996; Whitman et al., 1998; Willott et al., 2000; Fimbel et al., 2001; Costa et al., 2002; St-Laurent et al., 2007; Dennis et al., 2008; Corlett, 2009). To reduce the negative impacts of logging, mitigating measures in logging practices have been recommended (Marcot et al., 2001; Mason and Putz, 2001; Meijaard et al., 2006; IUCN, 2007).

Sustainable forest management (SFM) aims to balance sustainable timber production and environmental soundness (Cerutti et al., 2006; Dennis et al., 2008). Minimizing the impacts of logging on biodiversity is one of the important targets of SFM. SFM includes the allocation of exclusively protected areas where logging is not allowed, the adoption of reduced-impact logging techniques (RIL) to minimize the impacts of timber harvesting, the regulation of annual allowable cutting volume (AAC) and the establishment of a long cutting cycle to maintain the total standing stock. Since the 1990s, several forest certification schemes, such as that provided by the Forest Stewardship Council (FSC), have been formulated to promote SFM (Vogt et al., 1999). These schemes define the criteria and standards of SFM of forest management units (FMU) (Hanlon et al., 1989; Forest Stewardship Council, 1996). Some of the criteria and standards require management efforts to reduce the impacts on biodiversity and to monitor the achievements (Forest Stewardship Council, 1996).

Several studies have assessed the effect of RIL, a component of SFM, on biodiversity conservation (Davis, 2000; Azevedo-Ramos et al., 2006; Wunderle et al., 2006; Castro-Arellano et al., 2007; Presley et al., 2008; Dias et al., 2009; Bicknell and Peres, 2010). However, the other measures of SFM, including limitation of AAC and controls on hunting, can also contribute to maintaining biodiversity conservation and thus should be evaluated.

Mammals are a good indicator taxon for the evaluation of the effects of forestry activities on biodiversity for two reasons. First, the impacts of logging on mammals have been well studied and reviewed (Azevedo-Ramos et al., 2006; Davies et al., 2001), especially in Borneo (WWF Malaysia, 1982; Johns, 1988; Heydon

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and Bulloh, 1996; Meijaard et al., 2005; Wells, 2005; Wells et al., 2007). Species groups that are sensitive to logging activity in general have already been indicated (Meijaard et al., 2005). Bennett and Gumal (2001) found that the species richness of mammals in Borneo is not significantly affected by logging, but rather that species composition can be changed. The abundances of insectivorous and frugivorous species often decrease after logging (Heydon and Bulloh, 1996; Meijaard et al., 2005), while the abundances of ungulates species often increase after logging, perhaps because the increase in canopy openness promotes herbaceous growth on the forest floor (Davies et al., 2001; Meijaard et al., 2005). Therefore, the performance of improved forestry practices can be evaluated by testing these changes. Second, unlike other taxa, such as trees and most insects, medium-to-large mammals have an indicator character in their large area requirements and high vagility (Barlow et al., 2007; O'Brien et al., 2010). Animals with large area requirements are sensitive to landscape changes, such as habitat fragmentation (O'Brien et al., 2010), but conversely, local extirpation in small patches can be easily compensated for by immigration from surrounding habitats. Their presence/absence or abundance at a specific site may be determined not only by the local conditions at the site, which can be maintained by RIL, but also by the location of the site in the broader landscape, which is affected by the layout of the conservation area, the cutting sequence of compartments in the FMU, and the length of the cutting cycle. Due to the high heterogeneity of tropical rainforests (Ancrenaz et al., 2010), the abundances of animals that depend on small areas can be highly variable over a small spatial scale, but the abundances of medium-to-large mammals can represent the averaged habitat quality across a large spatial scale, thus providing a proper index for forest management.

In Borneo, the orangutan is the only species whose population status has been evaluated over the spatial scale of an entire FMU. Ancrenaz et al. (2004) developed a formula to estimate orangutan population abundance from nest density, which can be counted by aerial census. Using this method, they estimated the orangutan populations in all FMUs in Sabah (Ancrenaz et al., 2005). They found that 60% of the orangutan population in Sabah lives outside protected areas, such as national parks, and they indicated the importance of the timber concessions for their conservation (Ancrenaz et al., 2005). However, they also found that the orangutan is a disturbance-tolerant species, inhabiting even highly degraded forest (Ancrenaz et al., 2010). This indicates that the orangutan is not a sensitive indicator species.

The Deramakot Forest Reserve, Sabah, Malaysia, is directly managed by the Sabah Forestry Department under SFM principles as a "model forest" to improve forest management in that state. Deramakot has one of the longest histories of the implementation of SFM in tropical regions; the conventional logging system was stopped in 1987, and RIL has been conducted since 1995. As a result of various efforts of SFM, Deramakot has been certified as "well managed" under the FSC scheme since 1997. As part of the monitoring of impacts on biodiversity, the density of orangutans in Deramakot has been monitored annually by aerial census since 1999, and no obvious population decline has been detected over the past 10 years (Sabah Forestry Department, 2009). Several other studies conducted in Deramakot have commented on the effects of SFM on biodiversity conservation (Eltz et al., 2003; Akutsu et al., 2007), but no assessment of the net performance of SFM on taxa other than orangutans has yet been conducted.

In this study, we tested the performance of SFM for conserving various medium-to-large ground-dwelling vertebrates in Deramakot. While we have already demonstrated that conventional logging has significantly reduced the abundance of several vertebrate species in the forest reserve located adjacent to Deramakot (Imai et al., 2009), this study focused on areas within Deramakot, in particular on the differences between before and after harvesting by RIL. We assumed that the abundances of each species and species richness and composition would not be significantly different between the pre- and postharvested areas when RIL started in 1995 because the original forest conditions and logging histories of these two types of areas were similar until that time. Thus, we assumed that any differences in the species abundances and composition at this study period (in 2008 and 2009) were caused by the impacts of RIL.

2. Materials and methods

2.1. Study site

We conducted our field work in the Deramakot Forest Reserve over a period of 19 months from February 2008 to September 2009. Deramakot is located in the interior of Sabah, Malaysia (5°13–28′N, 117°19–35′E). The area of the reserve is 55,083 ha, and the altitude is 30–330 m above sea level. The annual rainfall is approximately 4000 mm with no clear seasonality (Sabah Forestry Department, 2005). Most of the area is covered by lowland mixed dipterocarp forest.

Deramakot is legally classified as a production forest and has been managed primarily for timber production (Sabah Forestry Department, 2005). Logging activity in Deramakot started in 1956, and almost all areas were conventionally logged up to 1987 (Sabah Forestry Department, 2005). During 1959–1968, timber, with a mean volume of 109 m^3 ha^{-1}, was harvested from the area (Sabah Forestry Department, 2005). Logging activity in Deramakot was halted in 1988 and then recommenced in 1995 under the SFM scheme. Under the current management, Deramakot is divided into 135 compartments (Fig. 1). Seventeen compartments (3473 ha or 6.3% of the area) are allocated to conservation, and the other 118 compartments (93.7% of the total area) are allocated to timber production (Lagan et al., 2007). However, parts of the production compartments are protected based on the steepness of the terrain or low density of harvestable trees. Hence, in total, 21% of the area of Deramakot is fully protected (Sabah Forestry Department, 2005). An inventory of the standing stock in all production compartments was conducted in 2002–2003 (Sabah Forestry Department, 2005). The results showed that the mean density of trees >60 cm diameter breast height (DBH) was 10.3 trees ha^{-1} (ranging from 0.2 to 26.4 trees ha^{-1} in each compartment), and the mean standing volume of trees >60 cm DBH in these production compartments was 50.8 m^3 ha^{-1} (1.0–121.8 m^3 ha^{-1}). To ensure long-term sustainability, the annual allowable cut (AAC) for Deramakot was set at approximately 20,000 m^3. Based on this AAC, one to three compartments have been harvested using RIL every year; a total of 20 production compartments (105,800 ha) was harvested from 1995 to 2006. The mean standing volume of trees >60 cm DBH in these postharvested compartments prior to harvesting was estimated to be 83.3 m^3 ha^{-1}, while the mean standing volume of the other production compartments was estimated to be 43.2 m^3 ha^{-1}.

Based on RIL, all harvestable trees were measured before harvesting and located on a detailed map and appropriate routes for skidders were designed to minimize the damage to non-target trees. The trees harvested were limited to those in the range of 60–120 cm DBH, and trees that were near streams, on steep terrain, with hollows, or of fruiting species for wildlife were excluded from harvesting. Tangling vines were cut before harvesting and targeted trees were harvested with a directional felling technique. Felled trees were partly carried out by a cable crane, but mostly carried out by ground skidding. Between 1995 and 2006, a total