The effect of forest fire on the Squirrel and Tree Shrew community dynamic in Southern Sumatra

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Abstract. A study to investigate the effect of forest fire on the dynamic of squirrel and tree shrew community was conducted in the south of Bukit Barisan Selatan National Park (BBSNP), Lampung, Indonesia. The park is surrounded by agricultural and plantation areas but contains some of the largest intact tracts of lowland forest remaining on the island which undergoing the most rapid forest conversion. The study focused on 8 squirrel (Ratufa bicolor, R. affinis, Callosciurus notatus, C. nigrovittatus, Sundasciurus hippurus, S. lowii, S. tenuis, and Lariscus insignis; Mammalia: Rodentia) and 3 tree shrew species (Tupaia tana, T. glis and T. minor; Mammalia: Scandentia) and described how pre- and post-fire conditions of habitat affect the density and distribution of squirrels and tree shrews in the study area. Data were collected before the fire in 1997, then each year subsequently after that until 2001. The study showed that density was significantly lower after the fire and in the burned area. The ground dwelling species were the most suffered species as fire destroyed their preferred disturbed habitat more severely than the undisturbed ones. The study has showed that fire caused changes in habitats and would change the structure of the animal community.

Keywords: Community dynamic, distribution, Indonesia, fire, population density, squirrels, Sumatra, tree shrews.

1. Introduction

Forest fire is noted to have serious consequences to the continued existence of the Indonesian rainforest. It has known to cause loss of primary forest, disruption of community dynamics, invasion of exotic plant species, and loss of biodiversity from parks and protected areas. Moreover, the damage caused by fire will increase the likelihood and severity of future fires. It will increase the susceptibility of the forest to successive burning [1, 2]. In Southeast Asia, fires associated with the El Nino/Southern Oscillation (ENSO) phenomenon are a recurring event. It is noted that major fires have occurred during five ENSO events within the past two decades [1]. Indonesia has also been experiencing large scale forest fires that have had profound consequences for the environment, vegetation and wildlife. These forest fires have been known to cause rapid habitat changes leading to local extinction of some plants and animals.

In order to protect plants and animals from the worst result of habitat changes namely multiple local or regional extinction, we need to understand how they respond to rapid changes in their habitat. Data on the habitat requirements of several coexisting species within one animal group well represented in all levels and in all types of the forest would provide a good model through which to pilot this approach.
The Southeast Asian squirrel species assemblage is ideal for studying such species-habitat relationships in the region. As rodents, squirrels can be found in almost any habitat, but unlike other rodents, they are active during the day, making them relatively easy to observe [3].

The study focused on 8 squirrel species (black giant squirrel *Ratufa bicolor*, pale giant squirrel *R. affinis*, plaintain squirrel *Callosciurus notatus*, black-striped squirrel *C. nigrovittatus*, horse-tailed squirrel *Sundasciurus hippurus*, Low's squirrel *S. lowii*, slender squirrel *S. tenuis* and three-striped ground squirrel *Lariscus insignis*) that are known to occur in Bukit Barisan Selatan. Among these species, both of the giant squirrels are listed on CITES appendix II [4]. The black giant squirrels is classified as endangered species [5] and under Indonesians law, this species and the three-striped ground squirrel are listed as protected species. Three tree shrew species (large tree shrew *Tupaia tana*, common tree shrew *T. glis* and pygmy tree shrew *T. minor*) were included in the study. Squirrel and tree shrew seemed to have similar habitat requirements and showed niche partitioning just like within the same animal groups [6]. Thus the inclusion of tree shrew in the study will increase our understanding of animal habitat relationship in this group of small mammals especially for the ground-living ones since there is only one species for the squirrel group.

A number of ecological studies have been conducted for these small mammal species in Peninsular Malaysia and Kalimantan [7-12] but none have been done to study their ecology in relation with forest fire. Nevertheless, extremely little is known about these species especially in Sumatra, to the extent that only some of them have local names: *Jelarang* for the giant squirrels and *bajing tanah* or *bajing ciong* for the three-striped ground squirrels. In this study, we describe the effect of forest fire on the dynamic of squirrel and tree shrew community in Bukit Barisan Selatan National Park, Lampung Southern Sumatra. This study which was conducted in Way Canguk Research and Conservation Training Centre, describes how forest structure and pre- and post-fire conditions of the habitat affect the density, distribution and community of squirrel and tree shrew species in the study area.

2. Methods

2.1. Study area

Bukit Barisan Selatan National Park (BBSNP) in the southwest tip of the Sumatran Island (4°31’–5°57’ LS and 1°3’34’–1°4’43’ BT) is the third largest protected area (3,568 sq. km) in Sumatra. It is and surrounded by agricultural and plantation areas but still contains some of the largest intact tracts of lowland forest remaining on the island and serves as primary watershed for southwest Sumatra [13]. Most of the park lies in the Lampung province, the most densely populated province of Sumatra and one undergoing the most rapid forest conversion [14].

The study was conducted in Way Canguk Research and Conservation Training Centre, a 900 ha study area in the south of BBSNP (5°39’325” LS and 1°4’24’21” BT, figure 1). It lies between 0–100 m above sea level. Annual rainfalls are between 1600 mm during the dry season up to 4000 mm during the wet season. Monthly rainfalls are between a minimum of 0 mm in the dry season and a maximum of 447.7 mm in the wet season. The study area usually has a short dry season between the months of June through September. The average minimum temperature is between 21.5–24.6°C while the maximum average is between 30.55–35.15°C [15]. The study area consists of remnants of primary forest, growing secondary forest and disturbed forest including forests damaged by fires. The study area is a grid by a set of transects forming 4 ha blocks. It harbours many unique and rare wildlife species of Sumatra. There are 56 mammal species from 26 families and 207 bird species from 41 families and these include the Sumatran elephant (*Elephas maximus*), tiger (*Panthera tigris sumatrae*), and rhino (*Discerorhinus sumatrensis*), 8 species of primates and 8 species of hornbill [16].
2.2. Data collection

2.2.1. Habitat. The habitat data was taken from a vegetation survey conducted in the study area in 1999. In the dry season of 2001 (June-August) more data on habitat parameters were recorded to be able to look at smaller scale of squirrel-habitat relationships. These data were collected at 238 intersections/nodes of a grid of trails spaced 200 m apart throughout the whole study area. At each intersection, the following data were recorded:

1. **Canopy cover.** Estimated at five locations at each point (the intersection and 4 points each at 10 m down the trail from the intersection and 2 m off the trail). Horizontal vegetation structure (understorey density), estimated at 4 points down the intersection and 2 m off the trail. It was measured by counting the number squares (25 cm x 25 cm) of a 1 m² grid that were at least 50% visible to a viewer standing at a distance of 10 m from the grid held at breast height by another surveyor. Full visibility was equal to 16 squares. The 10 trees (of ≥ 10 cm DBH) closest to the intersection (and not more than 15 m from the intersection) were selected and the following data recorded: DBH, distance from intersection and height.

2. **Vertical vegetation structure.** For this measurement, 3 plant types are recognized: seedling (≥1 m tall and ≥ 5 cm DBH), saplings (> 1 m tall and ≥ 10 cm DBH), and trees (all other plants). Point-quadrat canopy intercept measurements are taken at 4 points around each grid node. For each plant type, any branch or foliage vertically above the 4 points is scored as ‘1’, the absence of branches or foliage is scored as ‘0’ [17].

3. **Tree data.** For the 10 trees (of ≥ 10 cm DBH) closest to the trail intersection (and not more than 15 m from the intersection), the following data will be collected: crown connectivity, presence/absence of liana, and abundance of epiphytes. Crown connectivity: each tree is divided into 4 quadrats (using 4 compass points) around the trunk, then 2 observers decide whether the tree’s crown touches the crown of another tree within each quadrant. If it does that, it scores ‘1’ and if not scores ‘0’. Thus each tree can be scored 0 to 4. Presence/absence of liana: the presence of liana at 3 different heights on the tree: 0–10 m (usually the lower trunk of the tree), 10–20 m (usually the upper trunk of the tree), and > 20 m (usually in the canopy of the tree) is indicated with a ‘1’. An absence of lianas within a given height class will be indicated by a ‘0’. Abundance of epiphyte: the abundance of epiphytes on the tree will be score 0 to 3. No epiphyte will be scored ‘0’, 1–5 epiphytes will be scored ‘1’, 6–10 will be scored ‘2’, and more than 10 will be scored ‘3’.

4. **Litter thickness.** The depth of the litter is recorded to the nearest mm using a knife blade. Any coarse woody debris should be removed or the measured point should be relocated. Where thick
leaves are encountered, a knife should be used to cut a thin slit through the fresh litter [16]. Dead wood and ‘dry liana’. Four 10 m x 10 m quadrats will be developed at each point trail intersection using each of the four ‘10 m-down the trail’ section as the inner side of the quadrats. Within each quadrat, the following data will be taken: the abundance of fallen dead wood, the abundance of standing dead wood, and the abundance of ‘dry liana’. An observer will walk systematically through each quadrat counting the number of fallen branches, logs, etc. equal to or more than 10 cm in diameter, any standing dead wood with DBH > 10 cm, and any ‘dry liana’. Previous fieldwork suggested that tangled networks of dead/dry lianas and other branches were important to both squirrels and tree shrews (at least both groups of animals were frequently recorded in such vegetation). Thus we decided to record the abundance of ‘dry liana’. After careful observation and long discussion in the field, we decided to define ‘dry liana’ as follows: predominantly composed of dead branches and or liana (more dead materials than alive), dense (more branches/liana than open space), at least 1 m deep/thick, overall volume greater than 1 m³, and tangled.

2.2.2. Animal population. The population density of squirrel and tree shrew species was assessed using line transect method [18]. Data was collected before the 1997 fires in July-September 1997 and then after in July 1998, August-September 1999 and wet (January-March) and dry seasons (June-August) 2001. Each day, one or two teams consisted of 2 persons per team walked 2 or 4 trails covering a total of 2.4 to 8.8 km trails. Usually, the two teams walked along adjacent transects at a pace of 1 km per hour. Each transect was surveyed between 0600h and 1100h. Animals were recorded based on visual (seen) or vocal (heard) detections. To estimate the animal density, the distance between observer-animal and the sighting angle were recorded on each sighting of squirrel or tree shrew. When the object animal was seen, distances were measured either by estimation, pacing or using laser range finder while more rough distance estimations were carried out when the animals were heard. Height of animals above the ground was also recorded.

2.3. Data analysis

2.3.1. Habitat. Principal Component Analysis (PCA) and Discriminant Function Analysis (DFA) were used to analyse the environmental variables of this study. Environmental variables in terms of habitat parameters were measured on each point location in the study area. It was assumed that these parameters would determine the differences between the burned and unburned habitats thus furthermore could be used to explain the extent to which both habitats differ in their physical characteristics, such as vegetation structure. In this analysis, the habitat parameters measured in the field were first pooled into one data set for each point location that was previously assigned as burned or unburned based on the 1997 fire results [19]. Therefore, each of the 238 points location was predefined as burned or unburned area and each has the values for 36 habitat parameters. These data matrices were then subjected to ordination using PCA. First, all of parameters of habitat were used in the analysis then parameters with minimum weighting were excluded from the analysis. Several PCA were conducted until two extracted-components with the most significant effects were attained. The factor analysis scores were then determined for each point location from the analysis so that its positions could be visualized within two axis of the ordination space. Using the point positions identified from the PCA as the predefined habitat groups and the measured habitat parameters as the group discriminators, a DFA was used to determine the extent to which the burned and unburned habitat groups could be separated in terms of the measured environmental variables. It was assumed that if the groups could be separated on the basis of differences in any of the measured variables then these indicated differences in the two habitats.

2.3.2. Animal population. Present-absent of each species in the burned and unburned habitats during the course of the species were noted. Height choice differences among those species were analysed using Analysis of Variance (ANOVA) and post-hoc Duncan analysis.
The population density of each species or group of species in the burned and unburned area were calculated for pre- and post- 1997 fires. The densities were calculated using DISTANCE 3.5 release 5 [18]. Only two species (Lesser tree shrew and three-striped ground squirrel) and three groups of species (Callosciurus spp., giant squirrels Ratufa spp. and ground-dwelling tree shrew Tupaia spp.) had enough number of observations to make robust density estimation. The other species had considerably low sighting rates making their density estimation impossible.

The data were analysed separately between the burned and unburned area but in each area, the data was pooled among years to get adequate sample size for the selection of detection function models. Later in the DISTANCE analysis, the data were post-stratified by species. Two types of data were used for each species (and group of species): the combined visual and vocal detections and visual detections only. The distance data were grouped for analysis to overcome the problem of heaping in the data and outliers were truncated [18]. In this analysis, three different truncation models of 5 %, 8 % and 10 % were applied. In each case the data were manipulated to minimize the Akaika Information Criteria (AIC) for a particular model. Comparison among various grouping and truncation models was achieved using coefficient of variance (CV). The density estimates was chosen from the model with the lowest coefficient of variance [18]. Another ANOVA was performed for the overall mean density over time and across habitat types to see if there are any significant differences due to the effects of fire.

3. Results and discussion

3.1. Habitat characteristics in the burned and unburned habitat

In this study, the Discriminant Function Analysis (DFA) showed very small misclassification, thus the Principal Component Analysis (PCA) is good enough at classifying the parameters into each habitat types. Only thirteen misclassifications (5.5 %) were identified and these mostly come from point locations located in the edge of burned area, and few others probably from forest gap. These points were located in transition area between burned and unburned habitats (figure 2).

As many as 23 habitat parameters were identified using PCA. These habitat parameters characterized the 2 pre-defined habitat types: the burned and unburned area, and their distribution in those 2 habitat point locations were shown in figure 3. The unburned area characterized by more trees with high crown

![Figure 2. The distribution of point locations in the burned (yes) and unburned (no) habitats in Way Canguk study area, Lampung Southern Sumatra.](image-url)
connectivity, taller trees, epiphytes, liana and saplings, while the burned area was characterized by high canopy openness, high abundance of fallen branches, standing dead tree, ginger and herbs. The study area, before it was burned in 1997, has also been burned in 1992. The recurrent fires resulted in some disturbed habitats characterized by more canopy openness and ginger coverage compared to the undisturbed habitat [19]. During the 1997 fire, the fire mostly spread through that previously burned habitat causing a greater proportion and worse conditions of the area. Measures of canopy openness a year and two years after the 1997 fire has also showed a significant difference between the burned and unburned habitats. All Thus it was shown that canopy openness was one the major factors to determine the differences between the burned and unburned habitats in the study area, and this was still held 3 years after the fire. However, forest fire did not greatly change the upper canopy structure in the closed canopy forests. In this primary forest habitat, fire mostly spread through thick litter on forest ground and burned everything on its way [20].

3.2. Squirrel and tree shrew community

The dynamic of squirrel and tree shrew community in the study area can be seen from their occurrence in burned and unburned habitats over time with unburned habitat always had more species than the burned area from year to year. The ground dwelling species and the common squirrel were found in both habitats regardless of fire event in 1997. The horse-tailed squirrel seemed as the most affected species. It disappeared from both habitats after the fire in 1997 and needed 5 years to return in 2001 (table 1).

Apart from occurrence in different habitats, fire also affected the use of forest strata by this community. In general, squirrel and tree shrew species used different forest strata significantly (df = 30, F = 171.43, P < 0.05, table 2). This differentiation of strata use among the species showed that species from the same group or same characteristics would separate their niche to avoid resource competition.
Table 1. Species occurrence in the burned and unburned area across the year.

| Species                        | Burned Habitat | Unburned Habitat |
|--------------------------------|----------------|------------------|
|                                | 97 98 99 01    | 97 98 99 01      |
| Three-striped ground squirrel  | + + + + + +   | + + + + + +     |
| Ground tree shrew              | + + + + + +   | + + + + + +     |
| Low’s squirrel                 | + + + + + +   | + + + + + +     |
| Lesser tree shrew              | + + + + + +   | + + + + + +     |
| Slender squirrel               | + + + + + +   | + + + + + +     |
| Horse-tailed squirrel          | + + + + + +   | + + + + + +     |
| Common squirrel                | + + + + + +   | + + + + + +     |
| Pale giant squirrel            | + + + + + +   | + + + + + +     |
| Black giant squirrel           | + + + + + +   | + + + + + +     |

Table 2. Mean height of the squirrels and tree shrews above ground (m) in Way Canguk study area, Lampung Southern Sumatra.

| Species                        | N   | Ground Dwelling | Lower Canopy | Middle Canopy | Upper Middle Canopy | Top Canopy |
|--------------------------------|-----|-----------------|--------------|---------------|---------------------|------------|
| Three-striped ground squirrel  | 576 | 0.09            |              |               |                     |            |
| Ground tree shrew              | 961 | 0.3             |              |               |                     |            |
| Low’s squirrel                 | 26  | 4.7             |              |               |                     |            |
| Lesser tree shrew              | 136 | 6.5             |              |               |                     |            |
| Slender squirrel               | 13  | 11.4            |              |               |                     |            |
| Horse-tailed squirrel          | 47  | 11.8            |              |               |                     |            |
| Common squirrel                | 1255| 13.3            |              |               |                     |            |
| Pale giant squirrel            | 23  | 16.7            |              |               |                     |            |
| Black giant squirrel           | 118 | 25              |              |               |                     |            |

Looking at the community 5 years past the 1997 fires, burned and unburned habitats still had different quality. It was shown by height choices of the squirrels and tree shrews (figure 4). Ground dwelling species (*L. insignis* dan *T. tana*) were found slightly higher in the burned area maybe because in the study area fire had destroyed their ground habitat by spreading through thick litter on forest ground and burned everything on its way. *Callosciurus* spp. and *T. minor* chose slightly lower strata while *S. hippocus* and *R. bicolor* chose higher strata.

3.3. Squirrel and tree shrew density estimates

During the surveys in 1997 to 2001, a total of 358.78 km trail in the unburned area and 69.12 km in the burned area were surveyed. The total efforts in the unburned area were comprised of 33.43 km walked in 1997 (2 replicates), 59.43 km in 1998 (3 replicates), 66.23 km in 1999 (3 replicates) and 199.69 km in 2001 (9 replicates). The total 69.12 km walked in the burned area were consisted of 6.57 km walked in 1997, 12.57 km in 1998, 12.57 km in 1999 and 37.41 km in 2001. The density estimates of squirrel and tree shrew species used in the analysis were based on visual detection only because visual detection is considered more precise in detecting distance to the object animals, thus deriving more precise
estimates on density. Besides, there were no significant differences on the estimates of density based on visual only and combined visual and vocal detection (df = 63, F = 8.93, P < 0.001).

The overall mean density of all species was significantly lower in the burned area compared to the unburned area (df = 71, F = 2.3, P > 0.05, figure 5). This result suggested that there were negative impact of fire to the density of animal population in the study area that connected with the distinct conditions between the burned and unburned habitats in providing shelter, foods, etc. for the squirrels and tree shrew populations due to fire, with the unburned habitat is more favorable. Mean density of each species from all years combined also showed similar result (figure 6).

In the closed canopy forests, fire mostly spread through thick litter on forest ground and burned everything on the ground including dry seedlings, saplings and dead fallen logs [20]. Habitats with better canopy connectivity were clearly more preferred by the tree dwelling species which are the majority of the species under study [21] and this could explain how the overall density over the years were higher in the unburned area. Before the 1997 fire, this disturbed forest habitats were characterized with more ginger and thicker understory [19]. The habitats were also assumed to have more fallen logs/branches compare to the closed canopy forest due to more fallen tree/branches that probably resulted from bigger tree mortality caused by fire [20].

For all habitats combines, the mean density also differed significantly from year to year. Pre- and post-fire density of all species was differed significantly (df = 71, F = 2.31, P < 0.05) over 5 years of study. Density dropped after the fire but gradually returned to its pre-fire condition in 4 years. It is shown from that the overall animal density in the study area declined after the fire but gradually increased subsequently in the following years. It took approximately 3 years (1998 to 2000) for the populations to return to their pre-fire conditions. Density estimates were decreased in 1998, a year after the 1997 fire, but it increased significantly after 2 and 4 years. It was even shown that density estimates in 2001 was higher than in 1997 (figure 7).

Before the fire in 1997, the ground dwelling species equally used both the open- and closed-canopy habitats. The three-striped ground squirrel even chose the open habitats (burned area) over the closed habitat type (unburned forest). Therefore, when the burned area were burned again in 1997, the population dynamic of both species were seemed to be the most affected. Figure 7 showed that ground tree shrew (*Tupaia* spp.) showed the greatest decline post-fire but the strongest recovery over time and seemed to be the most suffered species among others. It was always the second most abundance group of species in the community except right after the fire (1998) when their abundance was lower than the abundance of three-striped ground squirrels. This was showed that the immediate effect of fire had bigger impact for this species compare to the others. The three-striped ground squirrel showed similar post-fire decline followed by recovery in 2001.

![Figure 4](image_url)

**Figure 4.** Species mean height above the ground in the burned and unburned habitat (year 2001).
Figure 5. Overall mean density of all squirrel and tree shrew species in the burned and unburned habitats.

Figure 6. Mean density of each species (or group of species) with its standard errors in the burned and unburned habitats.

Figure 7. Mean density before (1997) and after (1998-2001) the fire for each (line graph) and all species combined together (bar graph).
On the other hand, the common squirrels shown in lines, were relatively unaffected by the fire and had fairly stable density estimates across the years. This was probably due to less competition in the burned area right after the fire. The decline or disappearance of *T. minor* and *S. hippurus* a year after the fire has probably left empty niches for the common squirrel to occupy. Those three species were found at approximately same height average in the forest strata (table 2). Common squirrels might have occupied the other two species niches right after the fire. The impact of fire could not clearly shown in the population of *Ratufa* spp. because these giant squirrels were always relatively rare over the years and in both habitats. Even in the burned area they were always extremely rare.

Results of this study suggested that that the negative impact of fire in the study area might have taken place not just due to the 1997 fire but also its negative effect over a longer term of period. Looking at both temporal and habitat comparisons, again it can be seen that common squirrels were relatively unaffected by fire both in the unburned and burned areas. The ground dwelling species were the most affected because they were common in the ‘burned area’ as well as in the unburned. During the 1997 fire these species suffered the most. Up to a year after the fire, we observed very few ground dwelling species. The fire in Way Canguk was primarily a ground fire, creeping through the forest litter and burning everything on the ground. The typical disturbed habitat in Way Canguk contains thick understory cover and many fallen branches that provide protection and foraging substrate for ground dwelling species. As the fire moved through, these microhabitats were destroyed.

4. Conclusion

Fire was clearly caused fluctuation in the population and community of squirrels and tree shrews in Way Canguk study area. Among arboreal species, only the common squirrel was relatively unaffected by fire. The ground dwelling species were severely affected. From this study, it was shown that population change were most obvious a year after the fire where there were big shifting in densities of the species. The study clearly showed that the dynamic of the squirrel and tree shrew community in the study was negatively affected of recurring fire in their habitats.

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