Effect of forest fire on mammals: comparisons of species diversity on different time-period and area

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Abstract. Fire is one of the threats to biodiversity, although it also has a positive impact on particular species. It is important to understand the response of mammals to fire concerning its function as key components of the food webs and the essential role in the ecosystem. To investigate the impact of fire on mammal biodiversity, a 40 days observation was conducted on two period times (two years and four years after fires) at a sago plantation forest in Riau Province, Indonesia. A strip transect method as direct observation was used at three conditions (burned areas, unburned areas, and conservation areas) together with traps for indirect observations. Fires have an impact on decreasing the number of species, species richness, and composition of mammals at two years after the fire but do not cause the extinction of all mammal species. The fire also impacted the number of species gain and loss, where no addition to the number of species lost in two periods. Species begin to recovery after four years including adapted generalist species, e.g. \textit{Macaca fascicularis}. The presence of three different areas forms habitat heterogeneity that affects the diversity of mammal species in a post-fire habitat.
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1. Introduction
Fire is a natural disturbance that has shaped the evolution and dynamics of many tropical and temperate environments and profoundly influence people, climate, and ecosystem [1],[2]. The relationship between fire and biodiversity is complex [3],[4]. Fire is considered as a driver of biodiversity loss and influences plant communities over time. Fires can affect the succession process of vegetation, abundance, and diversity of plant species [5] and animals [6],[7]. Besides, fires can directly change the structure and composition of vegetation by burning biomass and dying of plant species in forest ecosystems [8].

Animals also experience changes in post-fire habitat that affects the composition of the animal community in the post-fire area, including mammals. Mammals are part of key components of the food webs and have the essential role in the ecosystem. However, wild animals' responses to fires show that not all fires harm wildlife [9]. Fires can recur over a period of time and form habitat types that increase species diversity, including small mammals [10]. Conversely, fires with large intensity and severe impacts, can have poor habitat quality for some species that are unable to adapt and consequently reduce the diversity of species of small mammal communities in ecosystems [11],[12].

Although the ecological impact of fires on forest ecosystems has been studied in various regions, limited information can be obtained regarding the impact of fires on tropical biodiversity. In Indonesia, fires occur almost every year on a fluctuating scale [13] on the land and forest areas. As a mega
biodiversity country, it is important to understand the impact of fire on mammals. To assess the effect of fire on mammals, we researched the sago plantation forest in Riau Province, Indonesia. Our objectives were to characterize the diversity of mammalian communities across a gradient of burned and unburned habitat after two time-periods.

2. Methods

2.1 Mammals Sampling
To compare the mammal’s similarity and obtain reliable indices of diversity between burned and unburned area at two time-periods, we conducted an inventory in the PT NSP area which is divided into burned and unburned areas as well as conservation areas. Data collection was carried out in 2017 (two years after fire) and 2019 (four years after fire) for 40 days.

Mammal data were collected using the direct method and the indirect method. The direct method used the strip transect method which runs on a path along 1000 m and width of 50 m on the right and left side. The observer runs constantly on the track with a speed of ± 10 m/minute. Observation was repeated four times. Species identification is carried out directly at the observation site by using mammal field guide. Observations began at 06:00 AM- 08:00 AM for morning observations, while afternoon observations were made at 04:00 PM-06:00 PM. Data recorded in a tally sheet include the types of mammals encountered, the number of individuals, substrate and mammalian activity encountered.

The indirect method used one to two traps placed on the survey transect. Indirect encounters can be through traces, scratch marks, food marks and feces. In addition, interviews were conducted regarding the presence of animals to the surrounding community and PT NSP workers. The data is recorded as additional data.

Figure 1. Study area in Kepulauan Meranti District, Riau Province Indonesia. Source: Google Earth (2019).

2.2 Data Analysis
The number of mammals found at unburned area, burned area, and conservation area was calculated on the richness and eveness of mammals using Margalef Index and Eveness Index [14], [15]. We also
quantify the similarity of mammals communities among the sites at the two time-periods using Sorensen index [15].

3. Results and Discussions
The results showed that two years after the fire, the number of mammal species in the burned area was lower than the unburned area and the conservation area. But after four years, the number of species in the burned area is higher than the unburned area, although it is still lower than the conservation area (Table 1). This is inversely proportional to the number of individuals, where the number of individuals after two years has increased, but after four years after the fire, the number is lower than the unburned area.

| Table 1. Number of mammals in each site and 2 time-periods of observation. |
|---------------------------------------------------------------|------------------|------------------|------------------|------------------|
| Conservation area | Unburned Area | Burned area | Conservation area | Unburned Area | Burned area |
| S                  | 4              | 6            | 5              | 3              | 1         | 2         |
| N                  | 23             | 12           | 19             | 25             | 24        | 21        |

Note: S =Total of species, N= Total of individu.

Among all species, *Macaca fascicularis* (long-tail monkey) is the most common mammal species found in burning areas. The number of individuals found has increased from their encounters in 2017. In 2019 or four years after the fire, 20 long-tail monkey individuals were found from the previous number of only 14 individuals in 2017 (Table 2).

| Table 2. List of types of mammals found at each type of location. |
|---------------------------------------------------------------|------------------|------------------|------------------|------------------|
| Local name          | Scientific name  | Location         | Conservation area | Unburned Area | Burned area (2 years) | Burned area (4 years) |
| Babi Berjenggot    | *Sus Barbatu*s | 0                | 0                | 1              | 0         | 0         |
| Bajing kelapa       | *Callosciurus notatus* | 5            | 2                | 0              | 0         | 0         |
| Berang-berang Sumatera | *Lutra sumatrana* | 1              | 0                | 2              | 0         | 0         |
| Lutung Simpai       | *Presbytis melalophos ssp. Sumatranus* | 0       | 1                | 0              | 0         | 0         |
| Monyet ekor panjang | *Macaca fascicularis* | 15           | 6                | 14             | 20        |          |
| Pelanduk            | *Tragulus kanchil* | 0              | 1                | 0              | 0         | 0         |
| Tikus belukar       | *Rattus tiomanicus jalorensis* | 0            | 0                | 1              | 1         | 1         |
| Tikus duri ekor pendek | *Maxomys whiteheadi* | 2            | 0                | 1              | 0         | 0         |
| Tikus ladang        | *Rattus esculans* | 0              | 1                | 0              | 0         | 0         |
| Tikus Rumah         | *Rattus tanezumi* | 0              | 1                | 0              | 0         | 0         |
| Total of individu   | 23             | 12           | 19             | 21             |          |          |
| Total of species    | 4              | 6            | 5              | 2              |          |          |

The high number of long-tail monkey individuals is related to their arboreal characteristics but has a high level of tolerance and adaptation to humans among other mammal species [16]. This mammal has a fairly wide habitat range and is commonly found in various types of forests including peat swamp.
forests [17]. The long-tailed monkey behavior is also influenced by the availability of feed [18]. They are frugivorous mammals or consume fruits [19] including the *Ficus benjamina* tree and other species that produce fruit throughout the year [20]. Besides, this species also consumes small insects and tree bark [16], [19].

The low number of species, causing the value of species richness index and evenness index does not increase, and even tends to decrease after two years after the fire compared to unburned land. In the second period after the fire, the richness value of mammal species decreased significantly with the index value difference reaching 1.03 (Table 3). The decrease in the level of diversity and evenness of mammal species is seen in the graph below (Figure 1).

### Table 3. Evenness and richness index of mammals species.

|                | 2 years after fire | 4 years after fire |
|----------------|--------------------|--------------------|
|                | Unburned Area      | Burned area        | Unburned Area | Burned area |
| Evenness       | 0.82               | 0.58               | 0             | 0.33        |
| Richness       | 2.01               | 1.36               | 0             | 0.33        |

The difference in the number of species found in each location also causes variations in the value of similarity and species composition between the two habitat type at each period. Both periods have a community similarity index value of less than 50% (Figure 2). This shows that very few of the same mammals were found in unburned and burned land cover. The community similarity index decreased in the two periods of data collection. During the first data collection period, there were 27% of the same types of mammals in both land cover, while in the second period (2019) only 17% of mammals were found in both locations.

![Figure 1](image-url) Changes in the value of richness and evenness index of mammals in the 2 periods after the fire.
Figure 2 The level of similarity in mammalian species community in 2 time periods.

The species composition similarity index illustrates the species loss and species gain in each land cover (Figure 3). After two years, 5 species were lost in the burned area and remain in that number until four years after the fire. The fire also impacts on species gain. There was an addition in the number of species on the burned area as much as 4 species after two years and 1 species after four years compared to the unburned area. This research reveals that fire does not cause the extinction of all of the mammal species. Many species still survive after the fire and start to recovery in two and four years later in the form of species gain. Many factors contributing to this condition and related to the ecological character of a species. The availability of trees and canopy greatly determines the distribution patterns of primates related to the availability of feed and habitat function. On burned area, generally there are no tree stands but pole stands that are needed by the Cercopitheceae family (long-tailed monkey group) as shelter and sleep.

Figure 3 Loss and gain of mammal species in burned area within 2 periods after the fire.

Another group of mammals found in the area after burning is pigs (Sus barbatus) belonging to Ungulata (hoofed herbivore). Ungulata is a group of mammals that benefit from fires. Fires cause plant succession which is a source of food for most groups of herbivores. Forest gaps formed by fire quickly recover after fires and support the growth of plant species. An increase in the number of undergrowth species indicates that fires cause succession with indirect effects [21]. Some research results in tropical
and nontropical regions prove that forest floor filled with understorey provides a source of food for herbivores and omnivores [22], [23]. In some non-tropical areas, this is the background of prescribed fires to stimulate vegetation growth for wildlife management [24]. Many animals adapt, develop, and depend on fire to maintain the bush.

Rat (Rattus tiomamicus) are also classified as mammals that can adapt to land after a fire. This mammal is also known as an omnivore species and is quite tolerant of habitat disturbance. Some literature states that the abundance of mammals, for example, deer, rats are most commonly found in post-burn locations compared to unburned locations [25]-[29].

In addition to responding to adaptable species, research results also show that fires can negatively affect several species that depend on the presence of poles and trees, such as coconut squirrels (Callosciurus notatus), Lutung simpai (Presbytis melalophos ssp. Sumatranus), horns (Tragulus kanchil), especially if there is no supporting habitat around the burned area. The level of effect is not uniform and appears to be associated with the specific habitat requirements of individual species and possibly body size, rather than broader factors such as phylogeny or conservation status [30]. Food sources, shelter and predators are some of the determinants of mammals. Fires can affect species density and composition and change habitat, in the form of loss or change in food availability including vegetation, shelter, and determine the diversity of species that will occupy post-fire habitats [26], [27]-[31].

3. Conclusions
Fires do not cause the extinction of all mammal species but have an impact on decreasing the number of species, species richness, and composition of mammals at two years after the fire. The fire also impacted the number of species gain and loss, where no addition to the number of species lost in two periods. After four years, recovery begins including highly adapted generalist species. The presence of three different areas (burned area, unburned area, and conservation area) form habitat heterogeneity that affects the diversity of mammal species in a post-fire habitat.

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