

## **The impact of fire on the termite assemblage in a tropical, degraded peatland**

By

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### **Abstract**

Fire is a common feature in tropical peatlands, particularly, in these recent years, during drought in association with El Niño events and land conversion to oil palm plantations. The phenomenon poses a massive threat to invertebrates and disrupts the integrity and biological functioning of ecosystems. Termites are seen as major soil engineers and if their services could be harnessed efficiently these insects could be a value to the peatland ecosystem at post-fire. A first step is to understand the termite assemblage in disturbed tropical peatlands, and toward that end we collected termite samplings in Riau, Sumatra. A total of 21 species representing 10 genera were identified. The relative species richness in the fire-impacted peat decreased up to 40% compared to an undisturbed peat swamp forest. Only four to ten species could be found in fire-impacted peats and the termite assemblage mainly consisted of members from the Rhinotermitidae. The species evenness indices demonstrated that there were significant effects of fire on termite species evenness in peats when compared with natural peat swamp forests. Similarity index significantly separated the termite faunal composition in peat swamp forests and fire-impacted peats where a major division was delineated at 39%. The relative abundance of termites detected did not change significantly along temporal variation.

**Key words:** peat fire, disturbed peatland, oil palm plantation, fire resistance, biological functioning

## **Introduction**

Over several millennia, fire has been of a common feature in the tropical peatlands, particularly during drought in association with El Niño events (Yulianti et al., 2012). The current event is also tightly linked to land conversion through slash and burn techniques to oil palm plantations (Langner and Siegert, 2009). Fire hotspot data captured by NASA MODIS illustrated that the highest hotspot density areas included the mass degraded peat lands in Kalimantan and Sumatra (Yulianti et al., 2012). The fires undisputedly pose a massive threat to invertebrates and indirectly disrupt the integrity and biological functioning of ecosystems.

Earthworms play role similar to termites and are also disturbance-sensitive. However, owing to the highly acidic peat ecosystem earthworms are absent from disturbed peat. Thus, termites are seen as major soil engineers post fire especially if their services could be harnessed efficiently. As a first step to understanding the termite assemblage in tropical disturbed peatlands, termite samplings were carried out in degraded peatlands in Riau, Sumatra.

## **Materials and methods**

This study was conducted in the transition zone of the Giam Siak Kecil–Bukit Batu Biosphere Reserve (0°44'–1°11'N, 102°11'–102°10'E) that lies between 0 and 50 m above sea level. Five burned peatlands (Peat1-5) were surveyed in this study. For comparison, two transects were employed at two undisturbed peat forests (Forest1 and 2). The termite samplings were carried out using a standardized belt transect (Jones & Eggleton, 2000). The belt transect comprised a survey area of 100 × 2 m and was divided into 20, 5 × 2 m sections. A collector spent an hour on each section. Potential termite habitats such as dead tree branches, logs, soil under logs, termite galleries, and nests were surveyed. Soldier and worker termites were collected and stored in 80% ethanol until identified.

To observe the termite abundance over the dry and rainy seasons, four termite samplings were conducted in November 2012, February 2013 and June 2013, and March 2014 at Peat4 and Peat5. The sampling times were based on the in-situ environmental and climatic variations (Neoh et al., 2015). At each sampling, transects were set 10 to 20m away from previously sampling sites.

Estimated termite species richness, diversity index, and similarity index in each landscape were generated using EstimateS Version 8.2 (Colwell, 2005). We employed the Chao2 estimator to extrapolate species richness beyond the observed data in the study site. Diversity indices (i.e., Shannon diversity index and Simpson's inverse diversity index) were calculated to infer species evenness at each surveyed site.

To determine whether the relative abundances of termites across seasons and locations were significant, we employed General Linear Mixed Models (GLMM) analysis with termite species

as the random effect. When testing the significance level of the relative abundances of termites across seasons, time of sampling was a fixed factor and location was treated as the covariate. The procedure was employed vice-versa when testing the significance of relative abundances of termites between locations.

## Results and Discussion

A total of 21 species representing 10 genera were collected. The relative species richness in fire-impacted peats decreased up to 40% compared to termite species found in peat swamp forest. Only four to ten species could be found in fire-impacted peats (Peat1-Peat5) and the termite assemblage mainly consisted of the subfamily Rhinotermitidae. Nevertheless, the differences in estimated species richness between forest and fire-impacted peats was not statistically significant as evidenced by overlapping of 95% confidence intervals.

The species evenness indices demonstrated that there were significant effects of fire on termite species evenness in peats when compared with natural peat swamp forests (Shannon's diversity Index:  $t(5)=6.356$ ,  $P<0.05$ ) except for Forest1 in which Simpson's inverse diversity index registering 5.78 ( $t(5)=1.969$ ,  $P>0.05$ ). The similarity index significantly separated the termite faunal composition in peat swamp forests and fire-impacted peats with a major division delineated at a similarity of 39% (Fig. 1).

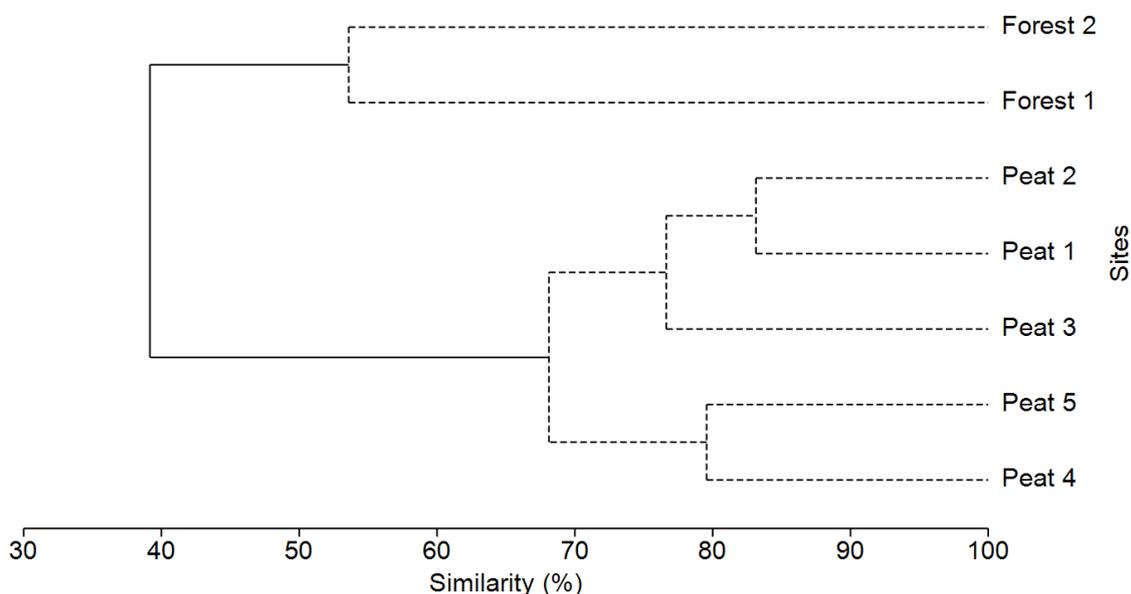


Fig. 1. Dendrogram of group-average clustering of the seven sites (two near forested peat sites and five fire-impacted peatlands based on means of Bray-Curtis distances. Solid lines represent significant differences among groups by SIMPROF tests ( $P<0.05$ ))

The fire behavior in peatland is characterized by high temperatures and long-lasting duration. For example, the progression of temperatures has been found to be at ground level as high as 400°C and at 5-cm below ground 200°C, at 10-cm 90°C, 20-cm 60°C, 3-cm 50°C, and 4-cm 45°C during a peat fire event (Usup et al., 2004). Further, a fire could result in smoldering that usually spreads laterally and downward to a depth of 20-60 cm to form a bowl-shape depression. This is the depth where termites nest and forage (20-30 cm below ground) (Kon et al., 2012). The likelihood of the peat fire exterminating both the arboreal and subterranean nest building termites is high.

The GLMM analysis showed that the relative abundance of termites detected along transects did not change significantly throughout the sampling carried out at selected time intervals in Peat4 and Peat5 (GLMM;  $F = 0.921$ ,  $P > 0.05$ ) (Fig. 2). In contrast, significant difference in termite abundance in fire-impacted peatland cultivated with oil palm (Peat5) was detected when compared with abandoned fire-impacted peat (Peat4) (GLMM;  $F = 4.341$ ,  $P < 0.05$ ) (Fig. 2).

In a given tropical fire-impacted peatland, the water table may register 20-cm from the soil surface and soil moisture of more than  $0.30 \text{ m}^3 \text{ H}_2\text{O m}^{-3}$  during the rainy season (Neoh et al., 2015). Peat inundation does not favor the survivorship of termites (Masijan, 2007). Nevertheless, the notion does not hold true in the present study as we found subtle changes in the termites represented in our temporal collections. We cannot explain precisely the reasons for this phenomenal but we should consider the nesting ecology of the surviving termites, i.e., tree bark.

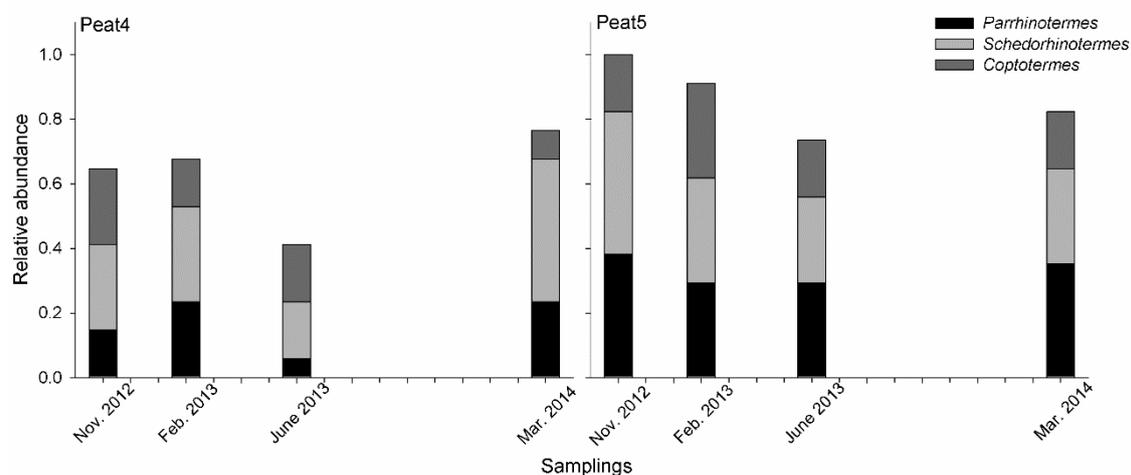


Fig. 2. Relative abundance of the termite assemblages based on the encounter rate on 20 sections in a standardized transect over time at long-burnt, abandoned peat (Peat4) and fire-impacted peat cultivated with oil palm (Peat5) in Sumatra. The termite species encountered were grouped by genera.

## References

- Colwell, R.K. (2005) EstimateS: Statistical estimation of species richness and shared species from samples *Version 8.2. User's Guide and application published at: <http://purl.oclc.org/estimates>.*
- Jones, D.T. and P. Eggleton 2000 Sampling termite assemblages in tropical forests: testing a rapid biodiversity assessment protocol. *Journal of Applied Ecology*, **37**, 191-203.
- Kon, T.W., C.F.J. Bong, J.H.P. King, and C.T.S. Leong 2012 Biodiversity of termite (Insecta: Isoptera) in tropical peat land cultivated with oil palms. *Pakistan Journal of Biological Sciences*, **15**, 108-120.
- Langner, A. and F. Siegert 2009 Spatiotemporal fire occurrence in Borneo over a period of 10 years. *Global Change Biology*, **15**, 48-62.
- Masijan, Z. 2007 Termite population in oil palm plantation and the effect of different water table on *Coptotermes curvignathus* in peat soil. Master, Universiti Malaysia Sabah, Sabah.
- Neoh, K.-B., L.-J. Bong, A. Muhammad, M. Itoh, O. Kozan, Y. Takematsu, and T. Yoshimura 2015 Understanding the impact of fire on termites in degraded tropical peatlands and the mechanisms for their ecological success: current knowledge and research needs. *Ecological Research*, **30**, 759-769.
- Usup, A., Y. Hashimoto, H. Takahashi, and H. Hayasaka 2004 Combustion and thermal characteristics of peat fire in tropical peatland in Central Kalimantan, Indonesia. *Tropics*, **14**, 1-19.
- Yulianti, N., H. Hayasaka, and A. Usup 2012 Recent forest and peat fire trends in Indonesia: The latest decade by MODIS hotspot data. *Global Environmental Research*, **16**, 105-116.