SEASONAL DYNAMIC OF TERMITE FORAGING (ISOPTERA) IN CAT TIEN NATIONAL PARK (SOUTH VIETNAM)

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1. INTRODUCTION

Termites are one of the most important decomposers in tropical forest. As many other insects, they are sensitive to available water, so dry conditions affect their activity [1]. Southern Vietnam climate is tropical monsoon with two distinct seasons, namely rainy and dry season. During the rainy season forest appears to be overwatered, while in the dry season water becomes extremely limited resource [2]. Insect community is dependent on this climatic cycle and has very seasonal patterns of abundance. Termites evolved social structure and construct complicated shelters protecting animals from abiotic conditions, so their activity is less restricted by unfavourable abiotic conditions.

Despite crucial importance of termites in tropical ecosystems, their foraging activity is quite poorly studied due to technical difficulties. Many of termite species forage hidden in wood, in soil, or under leaf litter, animals are approaching foraging sites by underground passages [3, 4]. Nests by itself are very difficult to spot for some species as they are placed in soil and have no visible marks on surface.

Seasonal activity of termites in South East Asia forest ecosystems is poorly studied. In this work we aimed to study the seasonal patterns of termite activity in the forest of Cat Tien National Park in Southern Vietnam.

2. MATERIAL AND METHODS

Study area. Material was collected from November 2018 to August 2020 in the Cat Tien National Park (11º25‘N, 107º25‘E, about 120 m a.s.l.). The territory is covered by monsoon lowland forest with *Lagerstroemia calyculata*, *Tetrameles nudiflora*, *Afzelia xylocarpa*, and Dipterocarpaceae species being dominant in the upper canopy [5]. The forest is rich in epiphytes, lianas, and suspended soils, and forms several canopy layers. Leaf litter on the soil surface is present seasonally for about half of the year. The litter layer is quite diverse and consists of leaves of different species, branches and twigs, bark fragments, and also numerous logs of different size and stages of decay. Tree trunks are typically covered by crustose lichens or algae film, and occasionally by moss. Soil in sampling areas is classified as thin clayey brown tropical soil, or Dystric Skeletic Rhodic Cambisol (Clayic) according to the WRB system [6].

There is a monsoon climate in Cat Tien National Park with strongly marked dry and rainy seasons, a mean annual air temperature of 26° C, an annual rainfall of 2,470 mm. Rain mostly occurs in May-September [7]. In the second half of the rainy season, large areas in the forest are flooded for a period of up to several months. Dry season lasts from December to March while it could be no precipitation at all for some months.

Material collection. Material was collected on the forest routes in different forest types (Table 1). Routes examination was performed at the day time and at night time every month. During the May 2019 and August 2019, field data were not collected due to expeditions to other areas. Monthly examination of model routes included visual observation of forest floor and other open habitats (log surface, tree trunks, stone surface) and leaf litter examination, and also the space under logs. Chosen model routes and frequency of observations represent roughly the relative amount of different forest types in the Park. Route counting was performed in no rainy hours as activity of most animals are ceased during the rain and also rain decreases the visibility significantly so it may alter the results [8]. During the route counting all visible termite activity was recorded, mostly it was foraging activity, but for *Hospitalitermes bicolor,* it was also migration (Fig. 1). Aggregations of foraging termites were considered as independent ones if they were more that three meters away from each other.

Weather data (precipitation and temperature) are kindly provided by the team of Weather and Climatic observational Tower placed in Cat Tien National Park.

Table 1. Characteristics of model routes

Route name	**Coordinates**	**Examinations per month (daytime/nigh ttime)**	**Approx. duration of one examination, hours**	**Forest type**
Circle trail	N11° 25.647' E107° 25.601'	3/3	1.5	Lagerstroemia, Tetrameles, Afzelia, Ochrocarpus genuses dominated forest
Bau Sau trail	N11° 27.428' E107° 22.149'	1/1	2.5	Polydominated forest on tuff rocks
Afzelia trail	N11° 26.503' E107° 24.911'	1/1	1	Polydominated forest flooded for several month every year
Grasslands	N11° 24.981' E107° 25.505'	3/3	0.5	Open grassy areas with sparse bamboo and Dipterocarpus sp. trees
Waterfall trail	N11° 24.600' E107° 22.831'	1/1	1	Bamboo dominated area with different trees included
All trails		9/9	21	

Five model species of termites where chosen for observation based on their abundance and the impact on litter decomposition: *Macrotermes carbonarius* (Hagen), *M. gilvus* (Hagen), *M. malaccensis* (Haviland), *Hypotermes obscuriceps* (Wasmann), *Hospitalitermes bicolor* (Haviland). As two second species of *Macrotermes* are not possible to separate from each other in the field, they were united and further are referred as "*M. gilvus/malaccensis*". All other termite species recorded during observations were referred as "others". Identification of termites was based on communication with Belyaeva N.V.

Figure 1. Foraging of *Macrotermes carbonarius* in leaf litter

3. RESULTS AND DISCUSSION

Termites were actively foraging all round the year, but with different intensity from month to month (Fig. 2). Maximum of activity was recorded in April 2020, when 128 foraging spots of different termite species were recorded. In April 2019, termites' activity was much lower. The lowest activity was recorded in November and January 2019. At any month, at least 21 foraging spots of different species were recorded.

For many insects and saprotrophic invertebrates, the dry season is the period with the lowest activity if any, because water supply is very limited and insolation is very hard [9]. Termites have suitable conditions inside living nests, so they are able to make relatively short foraging expeditions outside during the hard time [10]. This ability gives them access to freshly fallen leaf litter in the peak of dry season, while most of other saprotrophes are unable to use it. Foraging activity of termites slightly increased in the second half of dry season 2020, being high even before first rains.

Quite opposite, foraging activity of termites was relatively low during the rainy season. It could be explained by little amount of available food source, mainly leaf litter and small twigs, on the ground, as the main part of supply was used in the first half of rainy season. Large areas of forest are flooded during the rainy season for short or even longer time, what could also negatively affect surface termite activity.

Termite community demonstrated drastic differences in abundance from month to month with absence of correlation with precipitation level or soil temperature ($p < 0.05$; $n = 20$). Probably it reflects more complicated patterns of activity affected by some other that precipitation and temperature factors. Also stochastic fluctuation in activity could reflect individual features of large termites' nests and its irregular activity as they do forage not every day. One big mound of *Macrotermes* has wide net of underground passages spreading for several meters around it, which workers use for forage in distant lands [3, 4]. Big patches of forest floor (tens of square meters) appear to be foraging area of one termite family, so the days one colony has little foraging activity highly affects the amount of recorded foraging. Also termites change daily their foraging area around the mound (for *M. carbonarius)* [3] for avoiding predators, therefore, foraging patches distanced from the counting route could be not recorded.

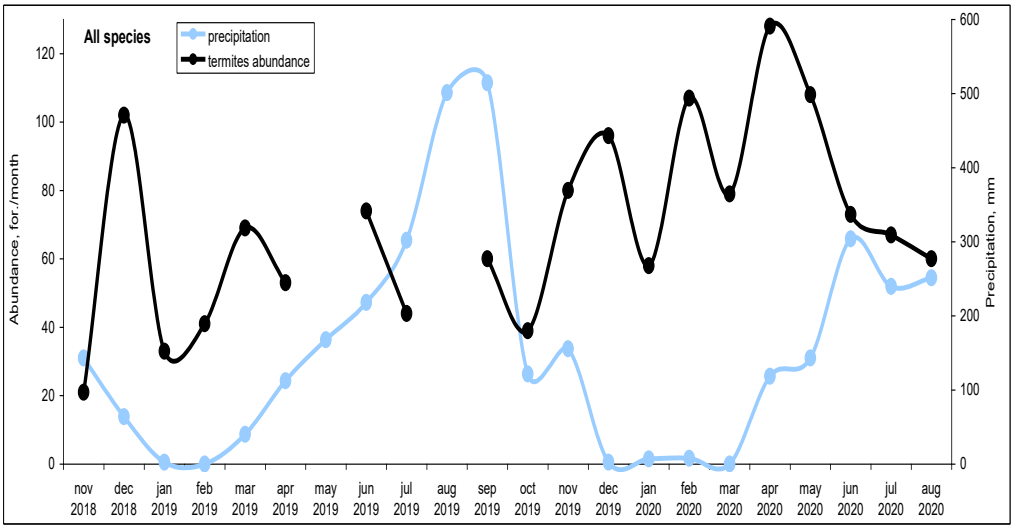

Figure 2. The dynamic of termite abundance and precipitation

The pattern of dynamic of termite abundance differed from year to year. In 2018 the peak of abundance was recorded in December, when rainfall started to lower, but in 2020 maximum of termites' activity was recorded in April, after the first rains.

Different termite species showed different dynamic of foraging activity. It is possibly correlates with the quality of nest protection, like species with modern nests are able to perform foraging activity in harsher conditions as they have more suitable conditions inside the nest. Species with simpler nests, like *H. bicolor,* have lower rates of protection, so have less energy and water storage for performing activity outside.

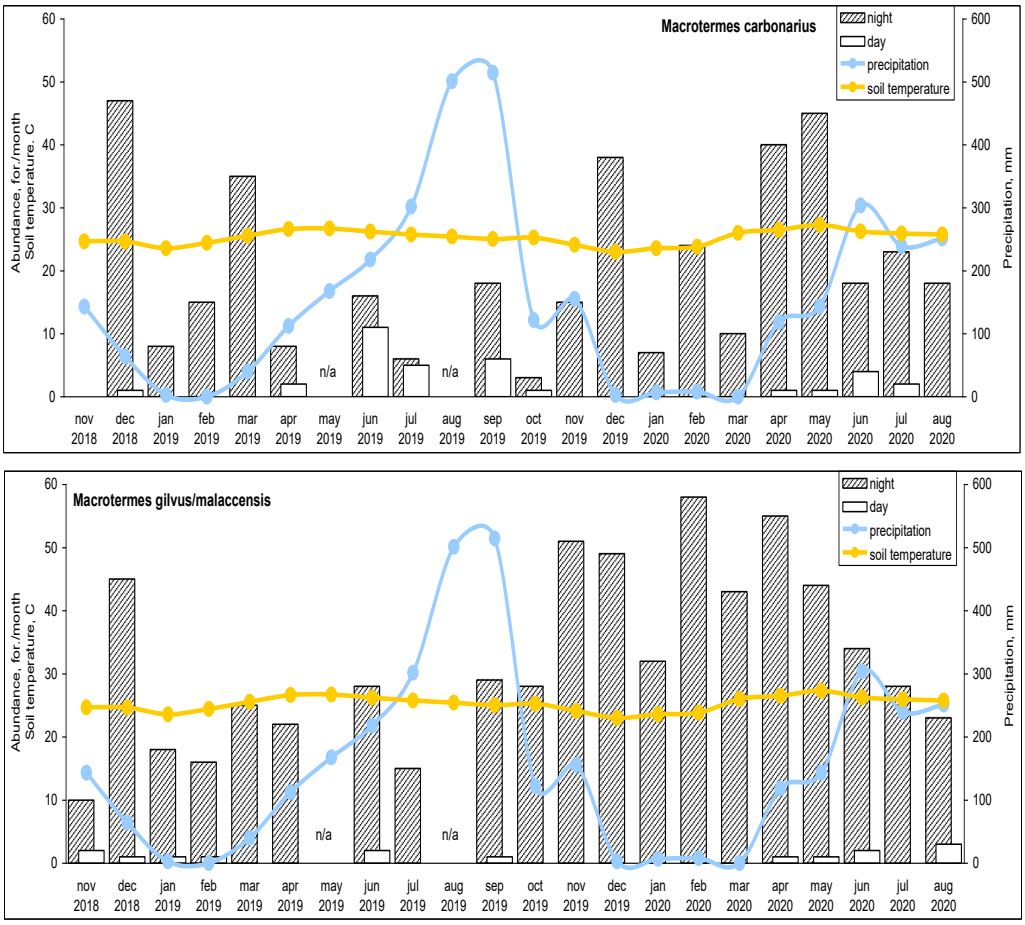

Figure 3. Dynamic of open-air activity of *Macrotermes* species

Macrotermes species demonstrated similar pattern of seasonal activity (Fig. 3). *Macrotermes* species were known to forage mainly at the night time and cease almost any open-air foraging activity in the rainy season [3], but we recorded open-air activity in the rainy season (June - September). Even more, only in the rainy season, termites foraged openly in the day time. Opposite to previous studies, termites' activity decreased in rainy season. The peaks of *M. carbonarius* open-air foraging activity happened in the between-seasons, while precipitation was moderate in comparison to extremes of dry and rainy seasons.

Both *M. gilvus* and *M. malaccensis* showed great open-air foraging activity in dry season (January - March), while *M. carbonarius* activity decreased in these month. The last species is more tolerate to dry conditions as has higher ability to decrease the water loss [11], so is supposed to maintain activity for longer in dry season. Probably *M. gilvus* and *M. malaccensis* have higher sensitivity to rains and they increase their foraging activity in any occasion, while *M. carbonarius* starts open-air foraging only after full start of rainy season.

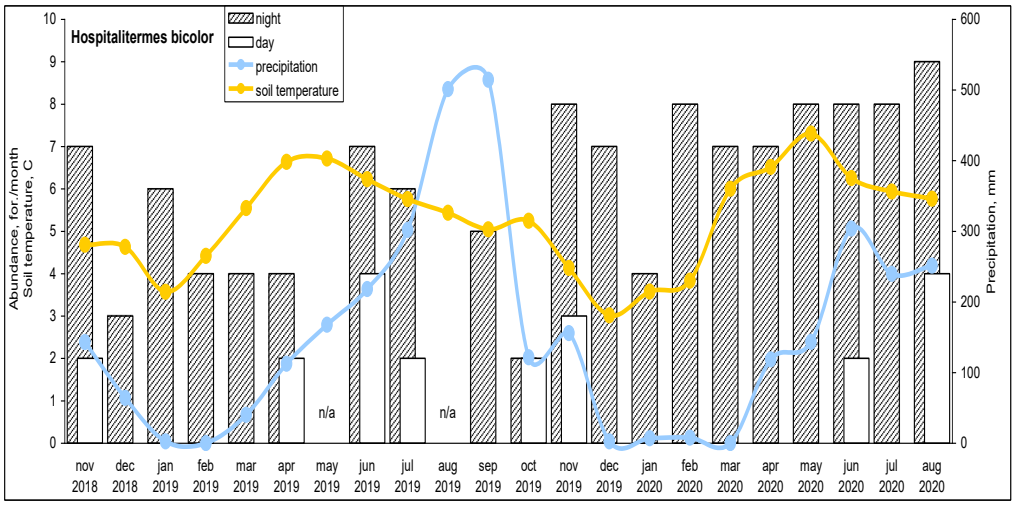

Figure 4. Dynamic of open-air activity of *H. bicolor*. Temperature is given not to the scale

H. bicolor is the only open-air processional termite species in studied forest, with no permanent mound, feeding mainly on lichens and algae [8, 12]. This species demonstrated high level of activity all round the year (Fig. 4). *Hospitalitermes* species were known to prefer night time for foraging [12], but in the rainy season we recorded daytime foraging activity as well as the night time. Night time activity decreased in the months with almost no precipitation, but increased again in 2020 before rains started. *Hospitalitermes* species are known to be resistant to limited water supply and live in quite arid sites [13], this ability may help them with foraging before rain season.

As for other model species, no correlation of foraging activity and the soil temperature was found. Termites are more limited by moisture than by temperature conditions. *Hospitalitermes* species are one of the most tolerate ones to harsh abiotic conditions (for Asian species) [14], this could be the reason of small fluctuations in foraging activity of *H. bicolor* around the year compare to another studied species.

H. obscuriceps had the lowest amount of activity records. This species has the smallest body size amongst other model species, workers usually forage under leaf litter and not appearing on the surface. Peak of foraging activity happened in the start of rainy season in 2020 and decreased with increasing rainfalls. In 2019 similar patterns though with smaller amplitude were found. During the months with high rainfall no forages of *H. obscuriceps* were recorded. *Hypotermes* species are foraging at lower depth in soil than *Macrotermes* species [15], this could be the reason of inactivation *Hypotermes* during temporal flooding in rainy months compared to *Macrotermes* species, and compared to *Hospitalitermes* species which are nesting often above ground level.

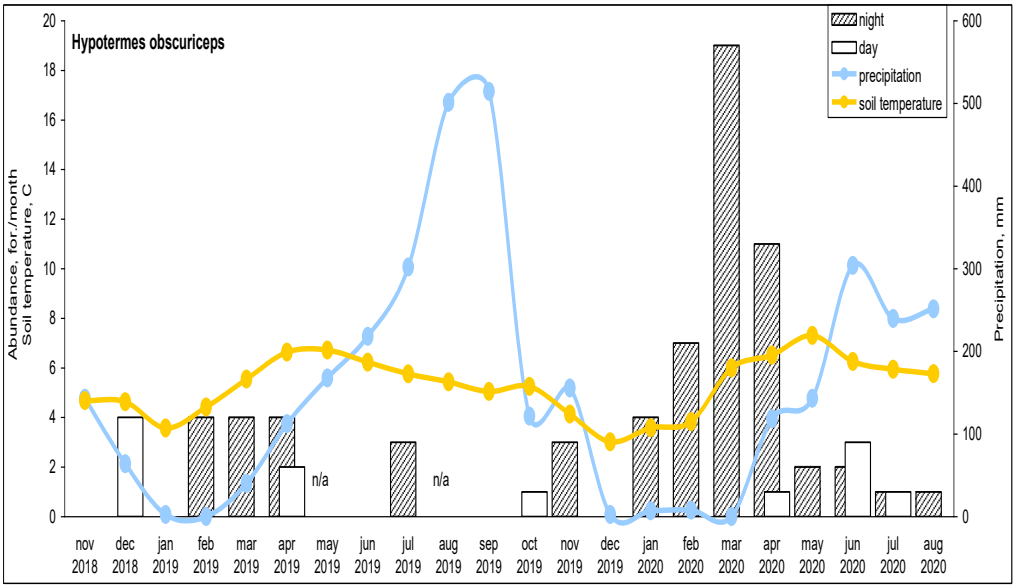

Figure 5. Dynamic of foraging activity of *Hypotermes obscuriceps*. Temperature is given not to the scale

4. CONCLUSION

We found that coexisting termite species different in ecological preferences, life history and the nesting type, differed in their seasonal patterns of activity. Termite community was foraging all round the year. Foraging activity despite the original hypothesis did not correlate significantly with precipitation level or soil temperature. Most of species increased foraging activity in dry months, but decreased it in months with heavy rains. In rainy season most of species demonstrated not only night time foraging activity typical for Asian termites, but also were actively foraging during the daytime. Termite species showed different strategies and adaptations to abiotic conditions, which allow the community to maintain decomposing activity all round the year. Further studies of seasonal aspect of termite community activity are needed for better understanding of the role of different species in the decomposing process in lowland monsoon forest in Southern Vietnam.

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SUMMARY

Foraging activity of five termite species, namely *Macrotermes carbonarius* (Hagen), *M. gilvus* (Hagen), *M. malaccensis* (Haviland), *Hypotermes obscuriceps* (Wasmann), *Hospitalitermes bicolor* (Haviland), was studied in Cat Tien National Park for two years with monthly performed route counting of open forages. Chosen model species differed in ecological preferences, life history and the nesting type. Termites community showed foraging activity all round the year. Foraging activity despite the original hypothesis did not correlate significantly with precipitation level and soil temperature measured monthly. Most of species increased foraging activity in dry months, but decreased it in months with heavy rains. In rainy season, most of species demonstrated not only night time foraging activity typical for Asian termites, but also were actively foraging during the daytime. During the dry season, foraging activity happened only in night time. Termite species showed different strategies and adaptations to abiotic conditions, which allow the community to maintain decomposing activity all round the year.

Keywords: *Termite, seasonal activity, foraging activity, South East Asia, Vietnam, ecology, mối, hoạt động theo mùa, hoạt động tìm kiếm thức ăn, Đông Nam Á, Việt Nam, sinh thái.*

Nhận bài ngày 18 tháng 10 năm 2022
Phản biện xong ngày 21 tháng 11 năm 2022
Hoàn thiện ngày 22 tháng 8 năm 2023

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