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Effects of tropical forest remnants on the assemblage of parasitoid wasps in the surrounding areas in Borneo

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Abstract To assess the effects of tropical forest remnants on the assemblage of parasitoid wasps in the surrounding areas, we conducted insect samplings with Malaise traps along line transects that were set up in a type of ecotone between isolated reserved forest (forest remnant) and its surrounding acacia plantation at Sampadi Forest Reserve, Lundu, Sarawak in Borneo. We set up three line transects, and five plots for Malaise traps in each line transect so that the five plots could represent five different locations in the gradient along the ecotone. Preliminary results from a few analyses of the samples showed that the relatively species-rich assemblage of parasitoid wasps in the forest remnants enriched the diversity of parasitoid wasp assemblage in the surrounding areas, where the species-richness of the assemblage had originally been relatively low, probably via dispersal by some species of parasitoid wasps from the forest remnants to the surrounding areas. We discuss several issues related to the results, and present some future research plans to solve these issues.

Keywords Forest fragmentation, Insect conservation, Insect diversity, Isolated primary forest, Landscape ecology, Southeast Asian tropic

Introduction

The extremely species-rich arthropod assemblages in primary tropical rainforests recently face a crisis of a drastic decrease of diversity because of the rapidly progressing degradation of rainforests, such as loss and fragmentation of rainforests in the Southeast Asian tropics (Sodhi et

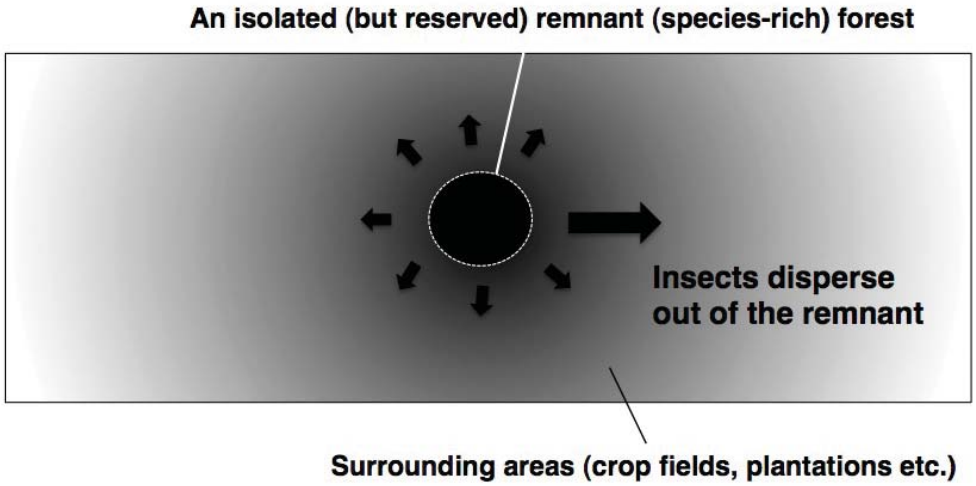

Fig. 1 Schematic illustration of the effects of isolated remnants of primary forest on the diversity and ecosystem service in the surrounding areas. The darkness indicates the species-richness or diversity of insects at a place. Arrows indicate the general trend of movement and dispersal by insects and supplies of insect species from the remnants to the surrounding areas. Dispersal of insects enriches the diversity and hence provides a kind of ecosystem service in the surrounding areas.

al. 2004, 2009; Edwards et al. 2012). Under such circumstances, isolated reserved forests are expected to harbor a considerable fraction of the diversity of arthropods, which exerts various effects on the ecosystems in the surrounding areas (Laurance et al. 1997; Kishimoto-Yamada et al. 2013). Remnants of primary forests, even though they are isolated, can function as a source of supply of diversified insects, especially those that are highly mobile with sufficient flying ability, for the surrounding areas (Fig. 1), and consequently the supplied diversity of insects could contribute to the enhancement of some kinds of ecosystem service that the insects perform.

From this point of view, Kishimoto-Yamada et al. (2013) investigated the effects of landscape with mosaic spatial structure of remnant primary forests on the biodiversity in the surrounding areas, which consisted mainly of vegetation types influenced by human land use, such as secondary or fallow forests and crop fields, in a tropical rainforest area in Southeast Asia. Based on their data on the diversity of dung beetles and ants, they suggested that the remnants of primary forest affect the biodiversity in the surrounding areas, and that the effects are different among arthropod taxa. For better understanding of the effects of forest remnants on biodiversity in the landscape, we need to extend the scope of target organisms for such kinds of studies. However, so far, the effects of landscape structures in relation to remnant forest distributions on the biodiversity have not been fully investigated for various kinds of organisms.

Parasitoid wasps (Hymenoptera) are one of the most diversified insect groups (LaSalle and Gauld 1992; Godfray et al. 1994). They function as important natural enemies contributing to regulation of various pest populations in agroecosystem planted forests and crop fields (Godfray 1994). Thus, the group is considered to be an appropriate target for the study of the effects of isolated primary forest as a source of supply of insect diversity and its associated ecosystem service towards the surrounding areas.

In recent years, we performed repeated sampling of parasitoid wasps by using Malaise traps in ecotones between isolated reserved forests and acacia plantations in a tropical rainforest

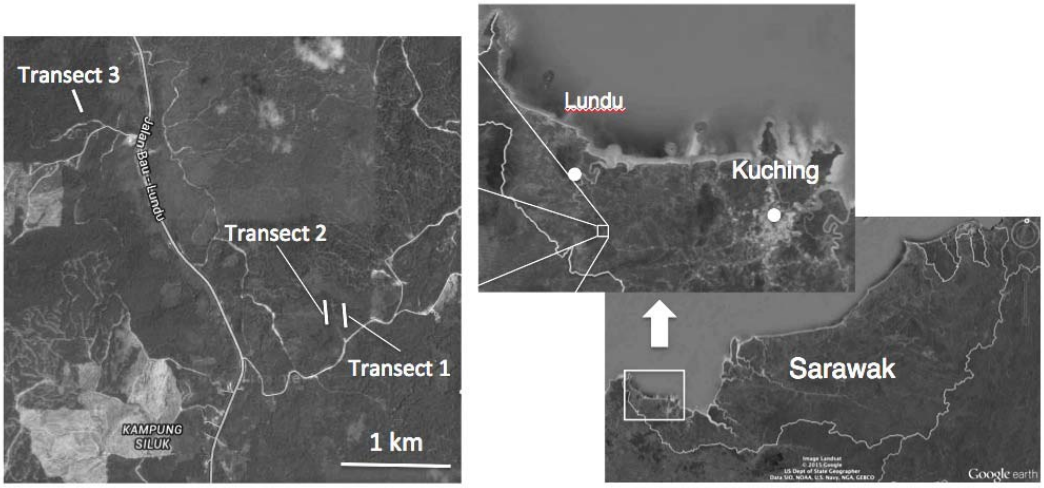

Fig. 2 Location map of the study site and the three transects.

area in Borneo in order to examine effects of isolated reserved tropical rainforests on the assemblage of parasitoid wasps in the surrounding areas. In this article, we briefly introduce the above-mentioned investigation and present a preliminary report of the results.

Study site

We conducted sampling of flying insects by using Malaise traps at Sampadi Forest Reserve, Lundu, Sarawak (1°36'N, 110°03'E, av. asl. 56 m, Fig. 2). Most of the landscape included in the site was originally covered by primary, lowland, mixed dipterocarp forests, was first logged in the 1970s, and was then used for shifting cultivation, which was done by local people who entered the site along the logging road (Vincent et al. 2003). Thereafter, the shifting cultivation was abandoned in the mid to late 1990s. Since 2007, the landscape surrounding the study site was mostly developed as forest plantation (*Acacia mangium*) and oil palm plantation. Throughout the above-mentioned history, a small part of the primary forest area has been reserved, though it has sometimes received a little human disturbance, such as selective logging and gathering of natural products, and though it has been becoming fragmented and isolated.

Sampling plots

We set up three 200-m-long line transects perpendicular to the borders of the two types of vegetation, isolated reserved forest and acacia plantation, so as to place each line along a type of ecotone between an isolated reserved forest and its surrounding acacia plantation (Fig. 3). The three transects were apart from each other: the distance was c. 150 m between Transect 1 and 2, and was c. 2,800 m between Transect 2 and 3 (Fig. 2). In each transect, we set up five plots for sampling using Malaise traps: two inside the reserved forest near the border (3–5 m distance from the border) and at 100 m distance from the border, and three inside the acacia plantation near the border (3–5 m distance from the border) and at 30 m and 100 m distance from the border (Fig. 3).

Malaise trap

Sampling using Malaise traps is an efficient method for sampling flying insects in tropical forest ecosystems (Campbell and Hanula 2007; Missa et al. 2009). Malaise traps are designed to efficiently collect flying insects by exploiting the general habit of flying insects that they tend to

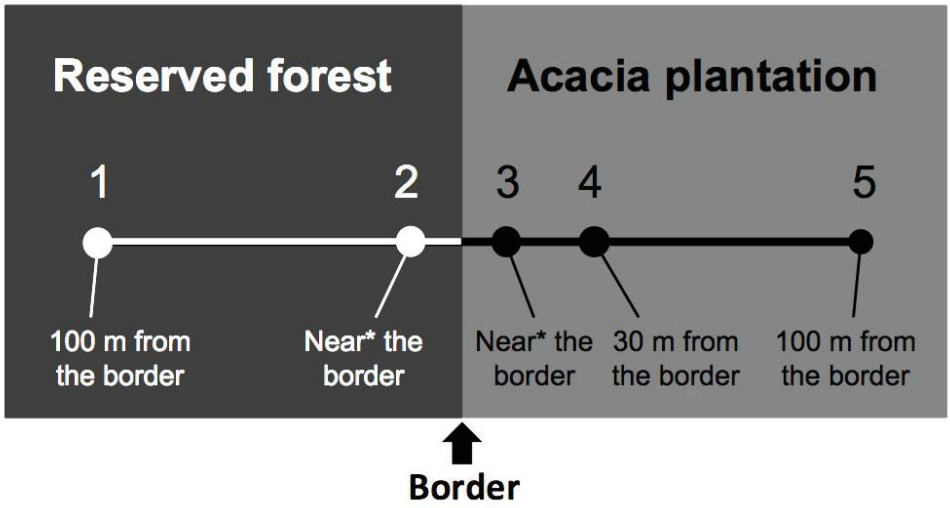

Fig. 3 Schematic illustration of the spatial design of five plots for Malaise trap set-up in each transect in relation to the direction and distance from the border of the two types of vegetation, isolated reserved forest and the surrounding acacia plantation. Plots 1 and 2 were located at 100 m and 3–5 m from the border, respectively, in the reserved forest. Plots 3, 4 and 5 were located at 3–5 m, 30 m and 100 m from the border, respectively, in the acacia plantation.

thus expected to be caught in a bottle filled with preservative fluid, set up at the top of the trap, as they fly up toward the ceiling after their flight is interrupted by the vertically suspended fine-meshed net (Fig. 4).

We conducted five separate samplings at intervals of 2–3 months from March 2012 to January 2013. In each sampling, insects were collected from each trap six days after its set-up. The bottle of each trap was filled with 99.0 % propylene glycol.

Collected wasps were stored in 85 % ethanol, mounted and identified by Maeto and Ito, taxonomists of parasitoid wasps, to species or morpho-species. Specimens were deposited in the insect reference collection of Research Development and Innovation Division (RDID), Forest Department Sarawak, Kuching.

Preliminary report of the results

More than 182 species belonging to five families (including three species of unknown families) were confirmed in the collection. The abundance of parasitoid wasps seemed to be higher in reserved forests than in acacia plantations. The species richness seemed to be highest at two plots (inside reserved forest and inside acacia plantation) near the border, second highest in reserved forests (100 m from the border), and lowest in acacia plantations (≥ 30 m from the border). Now we are performing some statistical analyses, such as general linear models with mixed models incorporating transect identity as a random factor to account for the non-independence of data points collected at the same transect, to test the significance of the observed differences.

In order to analyze the similarity in the species composition of parasitoid wasps among locations in the ecotone (along a transect), we plan to perform an analysis using non-metric multidimensional scaling (NMDS), to examine the species composition changes along the gradient of the ecotone. These results are expected to give us some information about how isolated reserved forest affects the diversity of parasitic wasps in the surrounding areas. We hypothesize that some

Fig. 4 A malaise trap set up in the acacia plantation area. The arrow indicates the bottle with propylene glycol.

fractions of the assemblage of parasitoid wasps in isolated reserved forests may emigrate outward and that they may enhance the ecosystem function as natural enemies regulating herbivore populations in the surrounding areas, where smaller numbers of parasitoid wasp species are inferred to occur opportunistically or unpredictably. In the near future, we are going to finish the data analyses and publish the total results as an original article in a journal.

Issues for the future

Using the methods that we described above, we did not set up any plots for sampling (Malaise trap) in acacia plantation areas that were more distant from the (nearest) isolated reserved forests. However, for more quantitative assessment of the effect of isolated reserved forests as a source of parasitoid wasps on the ecosystem in the surrounding areas at a larger spatial scale, we need to conduct similar sampling at much more distant locations in the surrounding areas. The data at such locations would contribute to a more detailed assessment of the relationships between distance from the reserved forest and parasitoid diversity, which would be reflected in the total effects of the isolated reserved forest on pest regulations in the surrounding areas.

In the current study of parasitoid wasps collected using Malaise traps, we have obtained little information about the detailed characteristics of each of the sampled parasitoid wasps, such as life cycle, life history, host range, host preference, dispersal ability, demographic traits, population dynamics and so on. However, for evaluation of the ecosystem services provided by particular species of parasitoid wasps, we need to get such information through various ways other than sampling using traps. In addition, the ability of parasitoid wasps to regulate the pests in agroecosystems in the surrounding areas should be directly assessed in the field for a total evaluation of the ecosystem services provided by isolated reserved forests.

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