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Spider diversity in canopies of Xishuangbanna rainforest (China) indicates an alarming juggernaut effect of rubber plantations

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ABSTRACT

We were interested in how forest type and complexity of vegetation influence the diversity of canopy spiders in the rainforest of Xishuangbanna, southwestern China. We sampled spiders by fogging tree canopies in four replicate sites of five different forest types once in the middle of the rainy season, forest types were tropical seasonal rainforest; monsoon forest; mountain rainforest; *Aporusa yunnanensis* forest; and rubber plantation. From a total of 20 sites and 1000 m^2 projected area we collected 4999 adult spiders of 472 species. Vegetational structure (number of plant forms, such as herbs, shrubs, trees, epiphytes and lianas), tree coverage, shrub coverage, grass coverage, tree height and elevation characterize the environmental conditions in different types of forest. Species richness and mean abundance differed significantly between rubber plantations and natural habitats. Rubber plantations harbored only 42.6–50% of the spider species in the natural forests, and 63.8% of the species in the *A. yunnanensis* forests. Spider guild composition also differed among forest types. Sheet-line weavers dominated the spider assemblages in natural forests with complex vegetational structure, such as tropical seasonal rainforests and monsoon forests. In contrast, cursorial hunters dominated forests with a more simple structure, such as rubber plantations and *A. yunnanensis* forest. These results show that intensive management practices in rubber plantations decrease the complexity of the vegetation and, so, strongly influence the diversity and composition of canopy spider assemblages. A lower intensity of management and the restoration of native vegetation may help balance the opposing needs of economic development and biodiversity conservation in this region.

1. Introduction

Globally, the loss and degradation of natural habitats results in the loss of biodiversity (Foley et al., 2005) and altered species distributions (Fischer and Lindenmayer, 2007). This may disrupt ecosystem functions and constitute a major threat to the long-term biodiversity conservation (Foley et al., 2005). The last few decades have witnessed an intensive destruction of tropical forests and replacement by plantations. In comparison to cropland, tree plantations and restored forests may conserve biodiversity and original ecosystem services. However, replacement forests will not match the composition and structure of the original forest cover (Chazdon, 2008). The rapid conversion of tropical forests has generated vast human-modified landscapes. Such developments potentially have dire consequences for tropical biodiversity (Foley et al., 2005; Laurance, 2007).

Xishuangbanna belongs to the Indo-Burma biodiversity hotspot (Myers et al., 2000). It has long been celebrated as being the most biodiverse area of China (Mann, 2009). In 1948, natural rainforest covered 67.7% of the area of Xishuangbanna. At that time, farmers widely practiced "slash and burn" agriculture. The quality and extent of natural forest declined continuously with the implementation of mechanized farming and an increasing population. These activities reduced the natural rainforest coverage of Xishuangbanna to 60% of the area by 1960 and to 51% by 1963. Five natural reserves were established in Xishuangbanna to protect the remaining natural forest, which covered approximately 240,000 ha, 12% of the total area (Li et al., 2007). Unfortunately, nature reserve policies have contributed to the continued loss of natural forests because land managers have considered the planting of rubber plantations to be a reforestation activity (Ziegler et al., 2009). A dramatic anthropogenic change from highly diverse tropical seasonal rainforest to monospecific rubber plantations has occurred in recent decades (Li et al., 2007; Li et al., 2008; Mann, 2009; Qiu, 2009; Ziegler et al., 2009). Currently, rubber plantations cover

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about 400,000 ha of Xishuangbanna Prefecture, representing 20% of the territory (Qiu, 2009).

Farmers usually plant rubber trees in sparse rows that form homogeneous and deciduous canopies. Frequently cultivation practices including the spraying of herbicides to kill weeds suppressed non-rubber vegetation. These activities result in a reduction of complexity of vegetation and a concomitant loss of biodiversity. For example, when compared with primary tropical forests, rubber plantations have greatly reduced diversity of plants (Zhu et al., 2004), birds (Aratrakorn et al., 2006), bats (Phommexay et al., 2011), and ground-dwelling arthropods (Zheng et al., 2009; Meng et al., 2012; Zhang et al., 2013). The removal of natural rainforest has catapulted the necessity of gathering biodiversity data that can be used to assess the consequences of land conversion to rubber plantations. Adept analyses of repeatable data can support conservation efforts, and a better insight can help managers to make decisions that maintain biodiversity and support the sustainable use of natural resources.

Spiders are key predators in forests, and they constitute relatively diverse and abundant components of the canopy fauna (Floren et al., 2011). Thus, spider assemblages can serve as indicators of biodiversity when comparing habitats because they are sensitive to a wide range of environmental factors, including habitat structure (Finch, 2005; Oxbrough et al., 2005). Unfortunately, no previous studies have focused on the effect of rubber plantations on canopy spider diversity in tropical regions of China.

Forest canopies represent the functional interface between 90% of Earth's terrestrial biomass and the atmosphere (Ozanne et al., 2003). They are among the most speciose yet most highly threatened terrestrial habitats. As concern for environment issues accelerates, studies of forest canopies are integral to understand biodiversity distribution, alterations of the global climate, and whole-forest interactions (Lowman and Wittman, 1996; Nadkarni et al., 2011). However, very few studies have addressed the changes in canopy spider assemblages in primary rainforests following anthropogenic disturbance in Southeast Asia (Floren and Deeleman-Reinhold, 2005; Floren et al., 2011).

Herein, we report on our investigation on the diversity, abundance, and distinctness of canopy spider assemblages across forest habitats that vary in vegetational structure. We focus on rubber plantations and contrast them with three natural forest habitats. We also sampled other tree monocultures of *Aporusa yunnanensis* (Euphorbiaceae) to generalize the effects of monoculture forests. Thereby, we (1) assess the magnitude of loss of diversity due to the conversion of natural forests to rubber plantations and (2) try to identify the causes of the decrease in diversity by correlating environmental variables with declines. Finally, from our results we (3) derive recommendations for forest (plantation) management for the conservation of biodiversity.

2. Materials and methods

2.1. Study area

The study was conducted in and nearby Menglun Nature Reserve, a subset of Xishuangbanna Nature Reserve, which was established in 1958. More specifically, collecting sites were near the town of Menglun (21°54′–21°58′ N, 101°11′–101°17′ E), Mengla County, Xishuangbanna Dai Autonomous Prefecture, Yunnan, China (Fig. 1). Lying in the East Asian monsoon region, the climate of Xishuangbanna is dominated by moist warm air masses from the Indian Ocean in summer and continental air masses from the sub-tropical regions in winter. The annual temperature averages 21.4 °C and annual rainfall averages about 1500 mm, of which 80% occurs in the rainy season (May–October; Li et al., 2012). The nature reserve partly consists of secondary forests regenerating from agricultural land prepared by slash-and-burn.

Twenty study sites (four repetitions for each forest type) were sampled in three natural forest types plus two types of monoculture (Fig. 1): tropical seasonal rainforest (TSRF), monsoon forest (MF), mountain rainforest (MRF), *A. yunnanensis* forest (AF; in fact, there are two sites of *A. yunnanensis* forest and two sites of *Paramichelia baillonii* (Magnoliaceae) forest, we just use the former as representative for ease of reading), and rubber plantation (RP). Forest types followed the classification of Wu et al. (1987). Details of the five habitats are given in Supplementary materials (Appendix 1, 2). To determine the vegetational complexity of each habitat where spiders were sampled, habitat structural diversity was defined by plant-form in five categories: (1) herbs, (2) shrubs, (3) trees, (4) lianas, and (5) epiphytes.

2.2. Spider sampling

Canopy fogging (pictures in Supplementary materials, Appendix 2) was used to sample spiders. All samples were collected between 19 July and 18 August 2007. Each sample site contained 50 m^2 of projected area from the canopy space. For each sample, ropes suspended at approximately 1.5 m above ground held 100 funnel-like 0.5 m^2 trays. A 50 mL tube with 25 mL 75% ethanol was placed at the bottom of each tray. On slopes, the traps were set in terraces. To avoid edge effects, fogging stations were established at least 50 m from the edges of forest. A portable thermal fogging machine (Swingfog SN-50, Germany, Model 2610E, Series 3) was used to disperse insecticide from the ground; fog drifted up through the canopy (Sørensen, 2004). For each sampling event, the fogger operated for 20 min and used 2 L of a 2.2% solution of pyrethroid dissolved in diesel oil as this dosage was proven to have low toxicity on vertebrates (Stork and Hammond, 1997). Fogging was conducted before sunrise to minimize fog-scatter because wind speeds were lowest at these times. Sampling never took place shortly after rain, or during windy or misty conditions. To prevent erroneous sampling of arthropods from the lower vegetational layer, small trees were bent and tied to the ground and low-lying branches were shaken to remove spiders prior to fogging.

The collecting trays were left for 2 h after fogging to maximize the number of arthropods sampled and to reduce the number of invertebrates escaping due to recovery from the toxic effects of the insecticide. All invertebrates were collected in the installed tubes and then preserved in 75% ethanol.

Adult spiders were sorted out and identified under a stereomicroscope. In case the adult spiders could not be determined as any known species, they were treated as morphospecies within the genus. Spiders were classified into four guilds according to their web-building and prey-catching behaviors following Sørensen (2004): (1) sheet-line weavers (SLW; Amaurobiidae, Dictynidae, Hahniidae, Linyphiidae, Pholcidae, Psechridae, Scytodidae, Sinopimoidae and Theridiidae); (2) orb weavers (OW; Anapidae, Araneidae, Mysmenidae, Nephilidae, Symphytognathidae, Tetragnathidae, Theridiosomatidae and Uloboridae); (3) ambush predators (AP; Ctenidae, Hersiliidae, Mimetidae, Oonopidae, Philodromidae, Sparassidae and Thomisidae); and (4) cursorial hunters (CH; Clubionidae, Corinnidae, Oecobiidae, Oxyopidae, Salticidae, Gnaphosidae, Lycosidae, Pisauridae and Zodariidae). All specimens were deposited in the Institute of Zoology, Chinese Academy of Sciences in Beijing (IZCAS).

2.3. Vegetational complexity

We recorded several environmental variables (Table 1) at each sampling site to explore factors that might be related to changes in the spider assemblages. These included forest age, estimated