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Epiphytic lichens in subtropical forest ecosystems in southwest China: Species diversity and implications for conservation

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ABSTRACT

Anthropogenic disturbances can severely impact the abundant lichen epiphyte communities of subtropical forests due to habitat loss, fragmentation and alteration. To assess the potential of anthropogenic secondary forests as conservation sites for epiphytic lichens, we investigated epiphytic lichens in 120 plots of eight forest types that are representative for the subtropical Ailao Mountains, southwest China. A total of 217 epiphytic lichen species were recorded, with 83% occurring in primary forests and 97% in secondary forests. Total species richness was significantly higher in the primary *Lithocarpus* forest (PLF), the middle-aged oak secondary forest (MOSF), the *Populus bonatii* secondary forest (PBSF) and the *Ternstroemia gymnanthera* secondary forest (TGSF) compared to four other forest types. The PLF harbored the highest number of rare species, while the MOSF, the PBSF and the TGSF, which had more pioneer tree species, hosted all cyanolichens found in this area. The Sørensen index of similarity between forest types ranged from 0.39 to 0.90. Ordination analysis showed a distinct lichen species composition in each forest type. Correlation analysis indicated that forest characteristics, such as canopy openness and host diversity, significantly influence lichen richness. These findings demonstrate the importance of primary forests for lichen epiphyte conservation, and suggest that the MOSF, the PBSF and the TGSF help preserve crucial components of the subtropical forest landscape and can play important roles in promoting lichen conservation. At a broad landscape scale, a mosaic of extensive primary forests and small secondary forest fragments is important for biodiversity conservation in subtropical regions.

1. Introduction

Evergreen broad-leaved forests, endemic to eastern Asia (Tagawa, 1995), are an important global vegetation formation in subtropical China and play a pivotal and irreplaceable role for biodiversity conservation (Ovington, 1983; You, 1983). As a consequence of long-term human disturbances, many of the evergreen broad-leaved forests in southwest China have been replaced by secondary forests, shrublands, tree plantations, and croplands. Habitat loss, fragmentation and degradation have led to changes in species composition and loss of the rare, endangered species (Liu et al., 2001; Tang, 2010; Wu and Zhu, 1987; You, 1983). The continuing threat of anthropogenic habitat transformation to the biodiversity of evergreen broad-leaved forests is one of the great challenges faced by conservation biologists in southwest China.

Epiphytes comprise a highly diverse group and improve the structural complexity and spatial heterogeneity in evergreen broad-leaved forests (Hsu and Wolf, 2009; Li et al., 2011; Xu and Liu, 2005; You, 1983). They are one of the first life forms sensitive to deforestation (Sodhi et al., 2008) and are likely to be dramatically affected by the transformation of primary forests to secondary forests (Zotz and Bader, 2009). Nevertheless, since primary forests are relatively rare, those undisturbed adjacent secondary forests becoming increasingly important habitats for epiphytes; it is therefore necessary to assess the potential conservation value of these secondary forests. If secondary habitats house the same or an additional community of species as primary forests, the preservation of secondary forests alongside primary forest habitats might decrease the local extinction rate.

In subtropical forests, lichens are a nearly ubiquitous group and form a key but poorly understood component of epiphytes. In general, primary or old-growth forests are thought to act as refuges for epiphytic lichens (Ellis, 2012; Marmor et al., 2011; Nascimbene et al., 2010). Studies in the boreal zone have demonstrated that epiphytic lichen richness is lower in secondary forests than in old-growth forests and that their diversity is controlled by stand

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characteristics such as stand age, host composition, tree density and canopy cover (Ellis, 2012; Fritz et al., 2008; Jüriado et al., 2003; McMullin et al., 2010). In particular, epiphytic cyanolichens are old-growth associated species and are particularly vulnerable to anthropogenic habitat fragmentation, degradation and loss (Hedenås and Ericson, 2004; Kuusinen, 1996a; McCune, 1993). In contrast, emerging evidence shows that secondary forests can enrich not only pioneer lichens (Holz and Gradstein, 2005) but also cyanolichens (Fedrowitz et al., 2012; Neitlich and McCune, 1997). Furthermore, some studies from subtropical areas have shown that macrolichen species diversity is distinctly higher in secondary forests, probably due to a constant input of propagules from nearby primary forests, high landscape connectivity, high host species diversity, and moderately open canopies (Li et al., 2007, 2011). Therefore, understanding the conservation value of primary forest remnants and regenerating secondary forests for epiphytic lichens can greatly aid conservation efforts in forest landscapes.

In this study, we examined differences in species diversity and assemblages of epiphytic lichens among eight forest types in the subtropical Ailao Mountains, which are a major feature of Yunnan Province, southwest China. Since the 1980s, a number of natural reserves have been established in Yunnan and deforestation is forbidden in these reserves (Liu et al., 2001). These protected primary and secondary forests are important habitats for epiphytes. To date, more than 450 species of epiphytes (113 angiosperms, 117 ferns, 176 bryophytes and 61 lichens) have been recorded in the Ailao Mountains (Li et al., 2007; Ma et al., 2009; Xu, 2007; Xu and Liu, 2005; You, 1983; Zhu and Yan, 2009). Although the lichen epiphyte community in this region is poorly understood, it is now receiving increasing attention for its biodiversity and the urgent need for conservation. Our objectives were to understand epiphytic lichen diversity among forest types in the subtropical Ailao Mountains and to evaluate the potential of secondary forests for lichen conservation.

2. Materials and methods

2.1. Study area

The study was conducted in the Xujiaba region (2000–2750 m a.s.l.), a core area of the Ailao National Nature Reserve (NNR), covering 5100 ha on the northern crest of the Ailao Mountains in central-southern Yunnan (23°35′–24°44′N, 100°54′–101°30′E). The NNR, with an area of 677 km^2, is one of the largest tracts of natural evergreen broad-leaved forest in China (Zhu and Yan, 2009). The mountain range is part of the Indo-Burma biodiversity hotspot and is recognized as a priority area for biodiversity conservation (Myers et al., 2000; Olson and Dinerstein, 1998). The mean annual precipitation is 1947 mm, with 85% falling in the rainy season from May to October. The average annual evaporation is 1192 mm, the annual mean temperature is 11.3 °C, and the mean relative humidity is 85% (Li et al., 2011).

The Xujiaba region has a gentle undulating topography and consists of eight forest types. About 77.9% of the total area is dominated by primary montane moist evergreen broad-leaved forest also called primary *Lithocarpus* forest (PLF), 6.7% by primary dwarf mossy forest (PDMF), and less than 16% by secondary forests. The forest landscape is hence characterized by an extensive area of continuous primary forests, archipelagos of small secondary forest fragments and high forest connectivity (You, 1983).

The PLF is dominated by the tree species *Lithocarpus xylocarpus* (Kurz) Markgr., *L. hancei* (Benth.) Rehder, *Castanopsis wattii* (King ex Hook. f.) A. Camus, *Schima noronhae* Reinw. ex Blume and *Stewartia pteropetiolata* Cheng, and is characterized by moist, shaded conditions, and an almost fully closed canopy (Qiu and Xie, 1998). The PDMF only occurs as an "island" of evergreen forest on a mountain top at 2600 m a.s.l. The canopy is exposed to frequent and intense wind and mist events throughout much of the year, and the dominant species are *L. crassifolius* A. Camus, *Rhododendron irroratum* Franch., *Clethra delavayi* Franch., *Ilex corallina* Franch. and *Gaultheria griffithiana* Wight. These primary forests are free from anthropogenic disturbances and include large, more than 300 years old trees (Wang, 1983; You, 1983).

The old-aged oak secondary forest (OOSF) experienced clear-cutting about 110 years ago but has since been free from human disturbance. It represents the advanced natural succession after cutting (Young et al., 1992). The middle-aged oak secondary forest (MOSF) developed after deforestation in the late 1950s and 1980s. Both secondary forests share most of their tree species with the nearby PLF, but community structure differs significantly between the three forest types (He et al., 2003; Young et al., 1992). The *Populus bonatii* secondary forest (PBSF) resulted from cutting and grazing in the last century. It is mainly dominated by pioneer *P. bonatii* Levl. and is associated with *L. hancei* and *Vaccinium duclouxii* (H. Lév.) Hand.-Mazz. The PBSF is widely believed to naturally succeed first to secondary oak forest (the MOSF and the OOSF) and finally to the PLF (Qiu and Xie, 1998). The *T. gymnanthera* secondary forest (TGSF, <20 year) is a very young vegetation adjacent to the MOSF and the PBSF. The tree layer is 3–5 m tall and is dominated by early secondary trees and shrubs such as *T. gymnanthera* (Wigrt et Arn.) Bedd, *V. duclouxii* and *G. forrestii* Diels (Qiu and Xie, 1998). The TGSF is characterized by shady conditions and small patch size (<0.01 ha). These four secondary forests have been well protected since the foundation of the NNR.

The *Alnus nepalensis* secondary forest (ANSF) and *Pinus yunnanensis* secondary forest (PYSF) also resulted from repeated cutting, fires, and grazing. The canopy of the ANSF is dominated by the pioneer tree species *A. nepalensis* D. Don, while the PYSF is dominated by *P. yunnanensis* Franch., *T. gymnanthera* and some *Lithocarpus* species. These two secondary forests can be described as the first stage of the secondary succession to the PLF and are also protected, but unlawful cutting may occasionally occur (Qiu and Xie, 1998; Wang, 1983).

2.2. Sampling method

Comprehensive fieldwork was carried out from October 2008 to June 2011. We randomly established 120 plots that differed in size due to differently sized forest areas and patches of different forest types in Xujiaba: 25 plots of 20 × 20 m in the PLF, 10 in the PDMF, 10 in the OOSF, and 15 plots in each of the other five secondary forest types (400 m^2 in the MOSF and the ANSF, 100–400 m^2 in the PBSF (plot size and lichen richness was not correlated: $r^2_{adj.} = 0.063$, $P = 0.367$), 10 × 10 m in the PYSF and 5 × 5 m in the TGSF).

In each plot, we counted and identified each tree with a height > 2 m and diameter at breast height (dbh) > 3.5 cm (dbh > 2 cm in the TGSF), and we then determined dbh, the maximum diameter of the largest tree (mdbh), host density, basal area, deciduous tree richness, deciduous tree density, and host diversity indices (species richness, Shannon–Wiener index and Simpson index). Canopy openness was measured at the beginning of the survey in those plots located in evergreen forests because the presence of deciduous trees had little effect on the canopy openness in these forests (You, 1983), while the canopy openness of the PBSF and the ANSF was measured in May and January. Canopy openness was visually estimated by the first author at 20 random points in each plot, and gave an average value in 10% classes. Additionally, we obtained the age of forests from available documentation (Deng et al., 1993; He et al., 2003; Young et al., 1992), employees of Ailaoshan Station, and the forest management authority.