SPECIES DIVERSITY, FLORISTIC COMPOSITION AND PHYSIOGNOMY CHANGES IN A RAINFOREST REMNANT IN SOUTHERN YUNNAN, CHINA AFTER 48 YEARS

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ZHU H, WANG H & ZHOU SS. 2010. Species diversity, floristic composition and physiognomy changes in a rainforest remnant in southern Yunnan, China after 48 years. In order to investigate the effects of tropical forest fragmentation, a comparative study on floristic composition, plant life forms and ecological species groups in a 13.9 ha remnant tropical rainforest was conducted over 48 years (1959/1960–2008) in southern Yunnan, China. A total of 258, 292 and 332 native seed plant species were present in the remnant in 1959/60, 1997 and 2008 respectively. A total of 407 species were recorded in the remnant from the three inventories, of which 188 species were common. Species diversity did not reduce with diminution and further isolation of the remnant. Species could condense with the limited natural habitats of the remnant with the loss of surrounding natural vegetation. There was a significant shift in floristic composition with 27.1% species of the original forest absent in the inventory in 2008 and 43.4% of the present species were new migrants. The species shift was greatly accelerated in the recent 10 years in the remnant with changes of surrounding vegetation into rubber plantations. There was a conspicuous shift in the relative representation of mature-forest and light-demanding species: the former decreased. However, plant life forms did not show significant change in the remnant over 48 years. Species loss was balanced by new migrants across life forms. Although species diversity was maintained and physiognomy (life forms) of the remnant did not change significantly, the floristic composition and ecological species groups were conspicuously changed through time. This implies that the essential flora of the tropical rainforest could not be actually maintained in the remnant. It is suggested that the flora of tropical rainforest cannot be protected from impoverishment even if the fragmented forests are conserved.

Keywords: Tropical rainforest, fragmentation, species richness, floristic shifts, implications for conservation


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INTRODUCTION


In southern Yunnan, China, some natural tropical rain forest remnants are conserved near local villages and usually are less disturbed for religious reasons (Liu et al. 2002). Local people generally call them ‘holy hills’. One of such remnants, which was part of a natural tropical seasonal rainforest in a former nature reserve became isolated in the late 1950s with rescission of the nature reserve for farms run by local government under the influence of the so-called ‘great leap in industry’, a nation-wide movement initiated by the Chinese government. However, the remnant has been less disturbed since 1960 due to its attribution as a ‘holy hill’ although it has been continually reduced in size. The remnant was floristically inventoried in 1959/1960. In 1997 and 2008, we made intensive inventories on the remnant again. Having historical and current data on the forest offers an excellent opportunity to investigate changes in species composition with time due to fragmentation. Thus, comparative studies on species richness, floristic composition, plant life form groups and ecological species groups in the remnant of tropical rainforest were made by comparing the historical records (1959/1960) with the inventories in 1997 and 2008 in this study so as to investigate floristic and physiognomic changes in the remnant over time.

MATERIALS AND METHODS

Study site

The study site is in a remnant of tropical seasonal rainforest on a holy hill near the village of Mangyangguan, which is located at 21° 35’ N and 100° 40’ E, at an altitude of 630 m, in Xishuangbanna, southern Yunnan (Figure 1). The remnant was part of a large forest patch in the early 1950s, isolated soon after and became completely isolated as a small patch in the late 1950s (tracing from references). From available Landsat Thematic Mapper (TM) images, which were used to create the land covers, the remnant was part of a large natural forest in 1950, but became isolated and was reduced to 30.04 ha in 1988, 18.37 ha in 1999 and 13.85 ha in 2007 and is surrounded by rubber plantations (Figure 2). The remnant in 2008 was still 13.85 ha in size. The region is influenced by a typical tropical monsoon climate. From the records of a local climate station, which is 15 km away from the study site and at the same altitude, the annual mean temperature is 21.3 °C and the annual temperature accumulation (the sum of daily temperature means of > 10 °C) is 7752.5 °C. Frost has never been recorded. The mean annual precipitation is 1426.9 mm. More than 80% of
the precipitation falls during the rainy season between May and the end of October. The annual mean relative humidity is 85%.

The soil is laterite, developed from siliceous rocks with a deep solum but a thin humus horizon. The pH is between 4.5 and 5.0.

**Inventories and data analyses**

The remnant of tropical seasonal rainforest on the holy hill was surrounded by primary forests in a former nature reserve. After Chinese–Russia expedition to the region in the late 1950s, an ecological research station of the Chinese Academy of Sciences was initiated and established at the foot of the holy hill in 1959. The tropical seasonal rainforest on the holy hill was fully inventoried by repeated transect walks, and plant specimens for all encountered species (except epiphytic plants on high branches and crowns of big trees, which were identified and evaluated by binoculars) were collected from 1959 till 1960. A 0.25 ha sampling plot was also laid out in the forest for phytosociological study. A primary plant list with 246 species from the inventory was compiled for reference. The plot data were published in an article on population structure of the tropical seasonal rainforest (Xiang 1981). The plant list from the inventory in 1959/1960 was revised by authors of the present article for verification of plant names based on herbarium specimens and floristic data accumulated from the region. The species in the remnant in 1959/1960 were identified and confirmed. We made intensive floristic inventories in the remnant in 1997 and 2008 by repeated transect walks. Voucher plant specimens were collected and identified. Complete plant lists of 1997 and 2008 were compiled. The floristic inventories of 1959/1960, 1997 and 2008 were compared to investigate species change over time. Plant life forms suggested by Raunkiaer (1934) and ecological species groups suggested by Whitmore (1989) were also compared based on these inventories to investigate physiognomic changes over 48 years. Voucher specimens were kept in the herbarium of Xishuangbanna Tropical Botanical Garden (HITBC). Species authorities follow *Flora Reipublicae Popularis Sinicae* (*Flora of China*).
RESULTS

Change in overall species diversity and composition

In 1959/60, 258 species of seed plants were identified from the remnant (Table 1). In 1997 and 2008, 292 and 332 species of seed plants respectively were present in the same remnant. Of the 258 original species, 47 species were not found in 1997 and 70 were not found in 2008. Of the species in 1997, 81 were new migrants compared with the list of 1959/60. Of the species in 2008, 68 species were new migrants compared with the list of 1997, but 144 species were new migrants compared with the original list in 1959/60. Of all 407 species recorded from the remnant in the three inventories in 48 years, 188 species were common (Table 1).

Changes in plant life forms and ecological species groups

Plant life forms and ecological species groups from the lists in 1959/1960, 1997 and 2008 were compared (Figures 3 and 4). Life forms did not show statistically significant change over 48 years, except that megaphanerophytes, mesophanerophytes and epiphytes were more diverse in 1959/60, while lianas were more diverse in 1997 and 2008. Among the 70 species that were present in 1959/60 but absent in 2008, 35 species were trees, 6 shrubs, 14 lianas, 3 epiphytes and 12 herbaceous plants. Among the 144 species new to the remnant in 2008, 54 species were trees, 18 shrubs, 39 lianas and 33 herbaceous plants. The missing species were similar to the new migrants across life forms, i.e. tree species > liana species > herbaceous species > shrub species. Although
Table 1  Species list for inventories in 1959/1960, 1997 and 2008 in the remnant tropical rainforest

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</table>

MG = megaphanerophyte, ME = mesophanerophyte, MI = microphanerophyte, NA = nanophanerophyte, LPH = liana phanerophyte, HPH = herbaceous phanerophyte, CH = chamaephyte, EP = epiphyte, G = geophyte, TH = therophyte, PARA = parasitic plants; + = present, - = not present, D = disappeared, NM = new migrant.
life forms did not show statistically significant change, there is an obvious trend towards the reduction of primary forest features.

For ecological species groups (regeneration strategy), the mature-forest woody plants (climax plus shade-tolerant) were more diverse in 1959/60, while the light-demanding plants (pioneers plus heliophiles) were relatively more diverse in 1997 and 2008. One of the conspicuous changes in ecological groups is an increase in ruderal species, especially after 1997. Among the total of 407 species recorded from the three inventories in 48 years, four ruderal species such as *Ageratum conyzoides*, *Capsicum frutescens*, *Chrysopogon aciculatus* and *Cyathula prostrate* were common through the time. A
total of three ruderal species such as *Solanum torvum*, *Synotis cappa* and *Thysanolaena maxima* were present in 1997 and another 16 ruderal species such as *Blumea balsamifera*, *Laggera alata*, *Malvastrum coromandelianum* and *Siegesbeckia orientalis* appeared in 2008 (Table 1). Except for these the ruderal species, four local invasive species were found in the remnant—*Eupatorium odoratum* was present in 1997 and thereafter; *Eupatorium coelestinum*, *Tithonia diversifolia* and *Syneudrella nodiflora* appeared only in 2008.

**DISCUSSION**

In 1959/60, 258 species of seed plants were recorded from the remnant, whereas in 2008, 332 species of seed plants were present in the same remnant, although it had reduced in size. The total number of species did not reduce with diminution and further isolation of the remnant. Species diversity at any one location is maintained because local extinction is balanced by immigration, even though the abundance of each species changes from one generation to the next (Primack & Hall 1992). In this study, species diversity was maintained but the total species richness increased over 48 years of forest fragmentation. The increase in the total species richness suggests that species could condense to the limited natural habitats of the remnant even when the surrounding natural forests were lost. However, there was a significant shift in the floristic composition in the remnant. A total of 70 species recorded in the remnant in 1959/1960 were not seen in 2008. The missing 70 species made up 27.1% species of the 1959/1960 records. In contrast, there were 144 new species in 2008 not represented in 1959/1960, contributing 43.4% of the total present species in the remnant. A shift in species composition took place in the forest remnant during the 48 years’ fragmentation.

If we look at species shifts between 1959/1969 and 1997, and between 1997 and 2008, the following were observed: 47 original species were missing in 1997, which made up 18.2% of the original flora, while 81 new migrants were recorded in 1997, which contributed to 27.7% of the flora in 1997. In contrast, 28 species in the flora of 1997 were missing in 2008, which made up 9.6% of the flora of 1997, while 68 new migrants were recorded, which made up 20.5% of the flora of 2008. From 1959/1960 till 1997, the rate of loss of species was 18.2% of the original flora and the new migrant rate was 27.7% of the flora. From 1997 to 2008 the species loss rate was 9.6% and the new migrant rate was 20.5% of the flora. It is clear that species shift was greatly accelerated in the recent 10 years in the remnant.

From the landuse and land cover data in 1976, 1988 and 2003 (Li et al. 2007), the tropical rainforests cover of 10.9% of the total area of the region in Xishuangbanna in 1976 dropped to 8.0% in 1988 and 3.6% in 2003. The high price of rubber promotes the expansion of rubber plantations in Xishuangbanna. The accelerated species shift in the recent 10 years corresponds to the rapid loss of tropical rainforest in the region. The study of surrounding vegetation on edge-related tree mortality in Amazonian forest fragments revealed that edge effects in forest fragments are significantly influenced by the structure of surrounding vegetation (Mesquita 1999). This study in southern Yunnan also revealed that species shift in the remnant was significantly influenced by the change of surrounding vegetation into rubber plantations.

Species shifts also occur in large protected forests. Tropical rainforest is considered to be a mosaic of gap, building and mature facies and is always in compositional flux in space and time. This is explained as ‘mosaic or cyclical of regeneration’ (Richards 1952, Brokaw 1989, Whitmore 1989, 1990). However, species shifts in forest fragments are evidently faster and bigger.

Studies on changes in species richness and floristic diversity between fragments and large protected forest patches in Mexico revealed that there was no significant difference in total species richness between fragments and large protected forest patches. However, changes were observed in the secondary or the early successional species and non-secondary or the mature-forest species (Arroyo-Rodriguez & Mandujano 2006), for example, a rise in the relative importance of ruderal species (Tabarelli et al. 1999). Studies on the functional attributes of tree assemblages in forest fragments of north-eastern Brazil revealed that a striking floristic drift took place in these edge-effected habitats (Santos et al. 2008). Our study also revealed that ecological species groups changed significantly in the
fragment with floristic shifts. The mature-forest (climax and shade-tolerant) species declined and early successional species became more important. One of the distinct changes is an increase in ruderal species. During the 48 years’ fragmentation, three ruderal species appeared in 1997 and thereafter, while 16 ruderal species appeared in 2008. These findings are similar to Tabarelli’s study in Atlantic fragment forests in Brazil. There were four most invasive species in the region, of which E. odoratum was present in 1997 and thereafter, while E. coelestinum, T. diversifolia and S. nodiflora appeared in 2008 in the remnant. Invasion of these species in the remnant corresponds to the quick change of surrounding vegetation into rubber plantations.

Turner et al. (1996) made a comparison between the historical records (herbarium specimens) and extant plant list from a 4 ha remnant of tropical rainforest in Singapore following more than 100 years’ fragmentation. He concluded that 50.9% species from herbarium records were lost from the forest, but 94 native species in the extant plant list were not in herbarium records. Venkateswaran and Parthasarathy (2005) made a comparison on changes in species composition and density of trees ≥10 cm girth in a 1 ha plot in a tropical dry evergreen forest of temple forest (similar to our holy hill forest in Yunnan) over a decade. They found that the total number of tree species rose by 21% (from 24 to 29 species), but about 11% of the total number of species within the plot was lost over the period. Immigration accounted for an increase of 27.6% of the species recorded. These examples, including our case, showed that the floristic shifts took place in fragmented forests over time.

Life forms in the remnant did not change significantly except for slight reduction of megaphanerophytes, mesophanerophytes and epiphytes, and slight increase of liana phanerophytes. Species loss was balanced by new migrants across life forms to some extent. This feature could explain that life forms did not show statistically significant change in the remnant. However, in the fragment of lowland tropical rainforest isolated more than a century in Singapore, 85.7% of herbaceous plant species, 73.3% of shrubs, 66.7% of epiphytes, 60.0% of lianas and 42.3% trees species were lost (Turner et al. 1996). In our study, 27.1% of tree species, 21.4% of shrubs, 25.0% of lianas, 23.0% of epiphytes and 38.7% of herbaceous plants were lost from the original flora in the remnant. The species loss was almost similar across life forms except for herbaceous plants with relatively higher ratio in the remnant in southern Yunnan, and was lower than the case in Singapore. The loss of herbaceous plants was balanced by distinct increase of ruderal species in some extent, so that life forms in the remnant in southern Yunnan did not change significantly. Our study also revealed that 9.6% of species was lost from 1997 till 2008, which was similar to a study in India by Venkateswaran and Parthasarathy (2005) with extinction within the plot accounting for 11% of tree species of the original inventory in a decade.

The microclimates in the remnant of our study site and the large protected forest of the same type were observed by Ma et al. (1998). The microclimatic disparity between the interior and exterior of the forest is less in the remnant compared with the large protected (primary) forest. For example, the differences in maximum air temperature, maximum soil temperature and relative air humidity between the interior and exterior of the forest were 6.1 °C, 28.2 °C and 37% respectively in the large protected forest, and 4.9 °C, 19.6 °C and 6% respectively in the remnant on the holy hill. Studies on edge effects of soil revealed that the differences of soil moisture and pH between the edges and the interiors were larger in the large protected forest than in the remnant. The differences in organic matter and extractable N between the edges and the interiors were distinctly greater in the protected forest than in the remnant. The extractable K was higher in the protected forest than in the remnant (Zhu et al. 2004). Floristic shifts in the remnant in southern Yunnan are strongly influenced by the edge effects of microclimate and soil.

In summary, the species diversity was maintained. Even though total species richness increased, the floristic composition and ecological species groups were distinctly changed in the remnant in 48 years of fragmentation. The maintenance of species richness does not mean that the flora of the rainforest can be maintained in the fragmented forest. Our results support the suggestions of Santos et al. (2008) that conservation policy guidelines will fail to protect ageing, hyper-fragmented landscapes from drastic impoverishment if the remaining forest patches are heavily dominated by edge habitat.
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