INFLUENCE OF SCENIC ROAD CORRIDOR ON PLANT DIVERSITY IN KUNYU MOUNTAIN, CHINA

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Abstract. The edge effect of forest communities in Kunyu Mountain Nature Reserve of China due to two small-scale roads was studied. By setting 3 groups of sample plots: sample plot beside 2.5 m road corridor, sample plot beside 5.0 m road corridor and sample plot in wildwood area, forest investigation was carried out using typical sampling method to evaluate and reveal the influence of edge effect (caused by 2.5 m and 5.0 m scenic road corridor) on the community structure, species composition and diversity of plants in Kunyu mountain national nature reserve. Results show (1) that compared with wildwood area, the average *DBH* (diameter at breast height) of tree layer at 2.5 m and 5.0 m scenic road corridor in Kunyu mountain national nature reserve decreases with the increase of width of road corridor. In shrub layer, edge effect is balanced by increasing the number of low-diameter shrubs while decreasing the number of high-diameter shrubs. It is worth noting that the edge effect of 2.5 m scenic road corridor is significantly higher than that of 5.0 m scenic road corridor. (2) In tree layer, the four indexes all showed as follows: sample plot near 5.0 m scenic road corridor was significantly higher than the sample plot near 2.5 m scenic road corridor and wildwood area. In shrub layer, the four indexes abovementioned can be ranked as sample plot near 5.0 m scenic road corridor>sample plot near 2.5 m scenic road corridor>wildwood area. In herb layer, the 4 indexes are ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor. Main conclusion: The 2.5 m scenic road corridor exerts an inhibition effect on the species composition and diversity of plants in Kunyu mountain national nature reserve, however, 5.0 m scenic road corridor has a promoting effect.
Keywords: *channel corridor, edge effect, species composition, plant diversity, Kunyu Mountain National Nature Reserve*

Introduction

Frequent human activities lead to habitat fragmentation and loss of species diversity. Under such background, continuous natural habitat is gradually replaced by fragmentated forest patches and the forest edge area is gradually increased (Lian and Yu, 2000; Velázquez et al., 2017). Corridor refers to linear or banded landscape element

which is different from surrounding landscape matrix (Zhu et al., 2005; Naidoo et al., 2018). Corridor can lead to change of ecological factors, thus making system components and behaviors (i.e. Population density, productivity and diversity, etc.) different from that inside of system (Wang and Ma, 1985; Chen et al., 2004). Road exists as corridor of landscape. The introduction of road enhances the fragmentation degree of landscape and the influencing area of edge effect (Zhou et al., 2009). Studies show that the edge effect of corridor causes the inhomogeneous distribution of species composition and diversity between inside and outside of plants community; The positive and negative edge effects are correlated with the area, shape, forming age, connectivity of forest patches as well as the property of neighboring patches. Therefore, research results on the positive and negative corridor edge effects are quite different (Sun et al., 2008; Wu et al., 2011; Liu et al., 2012). In fragmented forest patches, environmental factors such as solar irradiance, humidity and soil are normally in graded distribution from forest edge to inner forest. Therefore, the distance between inner patch to forest edge is correlated with corridor edge effect. The species composition, community structure and diversity also vary from forest edge to inner forest (Ma et al., 2008; Su et al., 2014). Since different plants have different sensitivities to habitat fragmentation, they have different strategies to get adapted to environmental change. For example, sensitive vs. tolerant species, trees vs. shrubs, shade-tolerance species vs. shade-intolerance species, evergreen species vs. deciduous species, they have different responses to edge effect; therefore, research results on corridor edge effect are different (Tian et al., 2011).

Studying the edge-induced community-based effects helps to understand the ecosystem changes caused by the road network, which may break the ecosystem integrity through the marginal effects of microclimates (García et al., 2007). The study of action characters of edge effect of scenic road corridor can provide data reference and theoretical basis for biodiversity conservation, balance of travel activities, and construction planning of future scenic road. In this paper, based on scenic road corridor of Kunyu mountain nature reserve as research objects, the property and action characters of edge effect of scenic road corridor were analyzed, in the hope of figuring out how the edge effect of scenic road corridor (2.5 m and 5.0 m) will affect the plants community structure, species composition and diversity.

Materials and methods

Profile of research area

Kunyu mountain national nature reserve locates at eastern shandong province, China, with geographical coordinates of 37°16′–37°25′ N, 121°42′–121°50′ E. It is the native place of Chinese red pine (*Pinus densiflora*) and the world's largest distribution of red pine (*Pinus densiflora*) forest, the best protected natural distribution center. It is one of the most biodiversity-rich regions in the world at the same latitude. It is the only place in the world to study the location of forest ecosystems for the project "Natural Control of Forest Pests". Kunyu mountain national nature reserve covers area of 48 km^2, with the main peak-Taibo Peak reaching an altitude of 923 m. The soil of Kunyu mountain nature reserve is mainly brown soil, which has a sandy texture, in acidic to slightly acidic condition. The climate here belongs to warm temperate continental monsoon climate, with four distinctive seasons, abundant sunlight, annual mean temperature at 11.9 °C and annual rainfall of 985 mm. Kunyu mountain national nature reserve is national forest park

and national 4A tourist scenic area. The forest coverage rate is about 92%, mainly consisting of red pine (*Pinus densiflora*), black pine (*Pinus thunbergii*), oak (*Quercus acutissima*) and locust (*Robinia pseudoacacia*) (Du et al., 2007).

Research method

Field investigation

Through reviewing literatures, inquiring forest management department and field investigation, forest investigation was carried out using typical sampling method (Fang et al., 2004; Fang et al., 2009). The investigation results show that the plant community was in natural growth and succession condition, i.e. indicating half-mature forest. The sample plot dimension was 20 m × 30 m. Three different sample plots were set, including sample plot near 2.5 m scenic road corridor, sample plot near 5.0 m scenic road corridor and sample plot at wildwood area. Five repeated investigations were conducted in each sample plot.

Investigations of plant species diversity were carried out in tree layer, shrub layer and herb layer. The research areas included one tree layer of 20 m × 30 m, 1 shrub layer of 10 m × 10 m and 4 herb layers of 1 m × 1 m. In tree layer, the species, number and *DBH* values of all trees with *DBH* ≥ 5 cm were measured; In shrub layer, the species, number and *DBH* values of all trees with *DBH* < 5 cm were measured. In herb layer, the species, number and heights of all herbs were measured (Fang et al., 2004; Fang et al., 2009; Wei et al., 2017).

Data analysis

Plant species diversity was analyzed and measured using general-purpose indexes (Leinster and Cobbold, 2012; Wei et al., 2017), including species richness index (*S; Eq. 1*), Shannon–Wiener diversity index (*H; Eq. 2*), Simpson diversity index (*P; Eq. 3*) and Pielou evenness index (*E; Eq. 4*).

$$S = \text{the number of plant species in sample plot} \qquad \text{(Eq.1)}$$

$$H = -\sum_{i=1}^{s} (P_i \times \ln P_i) \qquad \text{(Eq.2)}$$

$$P = 1 - \sum_{i=1}^{s} (P_i \times P_i) \qquad \text{(Eq.3)}$$

$$E = H / \ln S \qquad \text{(Eq.4)}$$

P_i refers to the ratio between importance value of the i-th species and total importance value in sample plot. The importance value of tree layer or shrub layer = (relative dominance + relative density + relative frequency) / 3, the importance value of herb layer = (relative dominance + relative density + relative frequency) / 3.

In the data analysis process, SPSS 17.0 software (Chinese version) and method of one-way analysis of variance and significance test was used.

Results

Species composition of tree layer

As shown in *Table 1,* the number of plant species in tree layer can be ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor; the number of plants in tree layer can be ranked as sample plot near 2.5 m scenic road corridor>wildwood area>sample plot near 5.0 m scenic road corridor; the mean DBH of plants in tree layer can be ranked as wildwood area>sample plot near 2.5 m scenic road corridor>sample plot near 5.0 m scenic road corridor.

Table 1. *Species, individual number and mean DBH of trees in wildwood area, sample plot near 5.0 m scenic road corridor and sample plot near 2.5 m scenic road corridor*

Tree name	Wildwood area		Sample plot near 2.5 m scenic road corridor		Sample plot near 5.0 m scenic road corridor	
	Plants number	Average *DBH*/cm	Plants number	Average *DBH*/cm	Plants number	Average *DBH*/cm
Pinus densiflora	201	10.06	338	10.57	109	11.83
Quercus variabilis	174	10.26	253	10.52	80	10.05
Pinus thunbergii	45	12.27			33	13.45
Quercus mongolica	37	15.08	14	13.79	27	10.74
Quercus hopeiensis	20	6.55				
Quercus fangshanensis	12	13.75	1	10.00	7	10.00
Albizia kalkora	8	5.00	11	10.18	22	8.36
Quercus acutissima	5	5.80			30	6.50
Sorbus alnifolia	4	5.00			4	10.25
Cerasus serrulata	2	5.55				
Pistacia chinensis	1	5.00	24	6.62	2	8.00
Lauraceae. obtusiloba	1	5.00			17	5.35
Salix matsudana	1	5.00			3	7.00
Malus baccata	1	5.00			1	5.00
Diospyros lotus			2	6.50	1	6.00
Robinia pseudoacacia			1	15.00	5	7.40
Rhus chinensis					56	7.21
Larix kaempferi					21	15.26
Ailanthus altissima					8	9.00
Symplocos paniculata					4	5.00
Alnus Sibirica					3	9.33
Catalpa bungei					2	20.00
Celtis koraiensis					1	5.00
Pterocarya stenoptera					1	5.00
Hovenia acerba					1	16.00
Fraxinus rhynchophylla					1	5.00
Cerasus serrulata var. pubescens					1	8.00
Amorpha fruticosa					1	5.00
Total	512	10.67	644	10.46	441	10.18

Species composition of shrub layer

As shown in *Table 2*, the number of plant species in shrub layer can be ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor; the individual number of low-*DBH* shrubs can be ranked as sample plot near 2.5 m scenic road corridor>sample plot near 5.0 m scenic road corridor >wildwood area; the individual number of high-*DBH* shrubs can be ranked as wildwood area>sample plot near 5.0 m scenic road corridor>sample plot near 2.5 m scenic road corridor.

Table 2. *Species, individual number of shrubs in wildwood area, sample plot near 2.5 m scenic road corridor and sample plot near 5.0 m scenic road corridor*

Shrub name	Wildwood area		Sample plot near 2.5 m scenic road corridor		Sample plot near 5.0 m scenic road corridor	
	DBH < 2.5 cm	*2.5 cm ≤ DBH < 5 cm*	*DBH < 2.5 cm*	*2.5 cm ≤ DBH <5 cm*	*DBH < 2.5 cm*	*2.5 cm ≤ DBH < 5 cm*
Indigofera kirilowii	147		372		89	
Quercus variabilis	154	43	209	56	81	19
Quercus mongolica	97	14	106	5	29	3
Cerasus glandulosa	37		106	1	71	1
Rhus chinensis	16		29	1	147	20
Lauraceae. obtusiloba	12	1			104	44
Quercus hopeiensis	96	47				
Leptopus chinensis	22		100	17	2	
Pinus densiflora	22	25	37	36	6	3
Lespedeza bicolor	34		65		21	
Albizia kalkora	37	9	21	1	43	7
Kalopanax septemlobus	17				80	6
Quercus acutissima	21	5	4	1	39	21
Euonymus phellomanus	52	6	19	1	7	
Grewia biloba	1		68		13	
Symplocos paniculata	12	1	11	4	29	12
Diospyros lotus	5		5	1	54	
Robinia pseudoacacia	15		27	1	17	2
Ailanthus altissima	18		6		35	1
Pinus thunbergii	26	13			11	6
Zanthoxylum schinifolium	32		13		5	
Euonymus alatus	8		13		14	3
Celastrus orbiculatus	8		22			
Ligustrum sinense	2		7		17	2
Pistacia chinensis	14	2	9	1		
Amorpha fruticosa	4		9		10	
Quercus fangshanensis	8	2	2	1	4	2
Cerasus serrulata var. pubescens	6				8	
Rosa multiflora			7		7	

Sorbus alnifolia	9	1			3	1
Celastrus flagellaris	3				9	
Ulmus pumila			6	5		
Fraxinus rhynchophylla	4		5			1
Ulmus macrocarpa					8	
Ampelopsis humulifolia			3		3	
Hibiscus syriacus					4	
Catalpa bungei					4	
Deutzia grandiflora			3			
Salix matsudana	1	1				1
Hovenia dulcis					1	1
Vitis amurensis					2	
Cerasus serrulata	2					
Celtis koraiensis			1			
Pterocarya stenoptera						1
Malus baccata			1			
Ziziphus jujuba var. *spinosa*			1			
Total	936	170	1292	133	983	157

Species diversity

As shown in *Figure 1A1–1A3,* the species richness index, Shannon–Wiener diversity index and Simpson diversity index of plants in tree layer can be ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor ($P < 0.05$). However, the Pielou evenness index is ranked as sample plot near 5.0 m scenic road corridor>sample plot near 2.5 m scenic road corridor>wildwood area ($P < 0.05$), as shown in *Figure 1A4*.
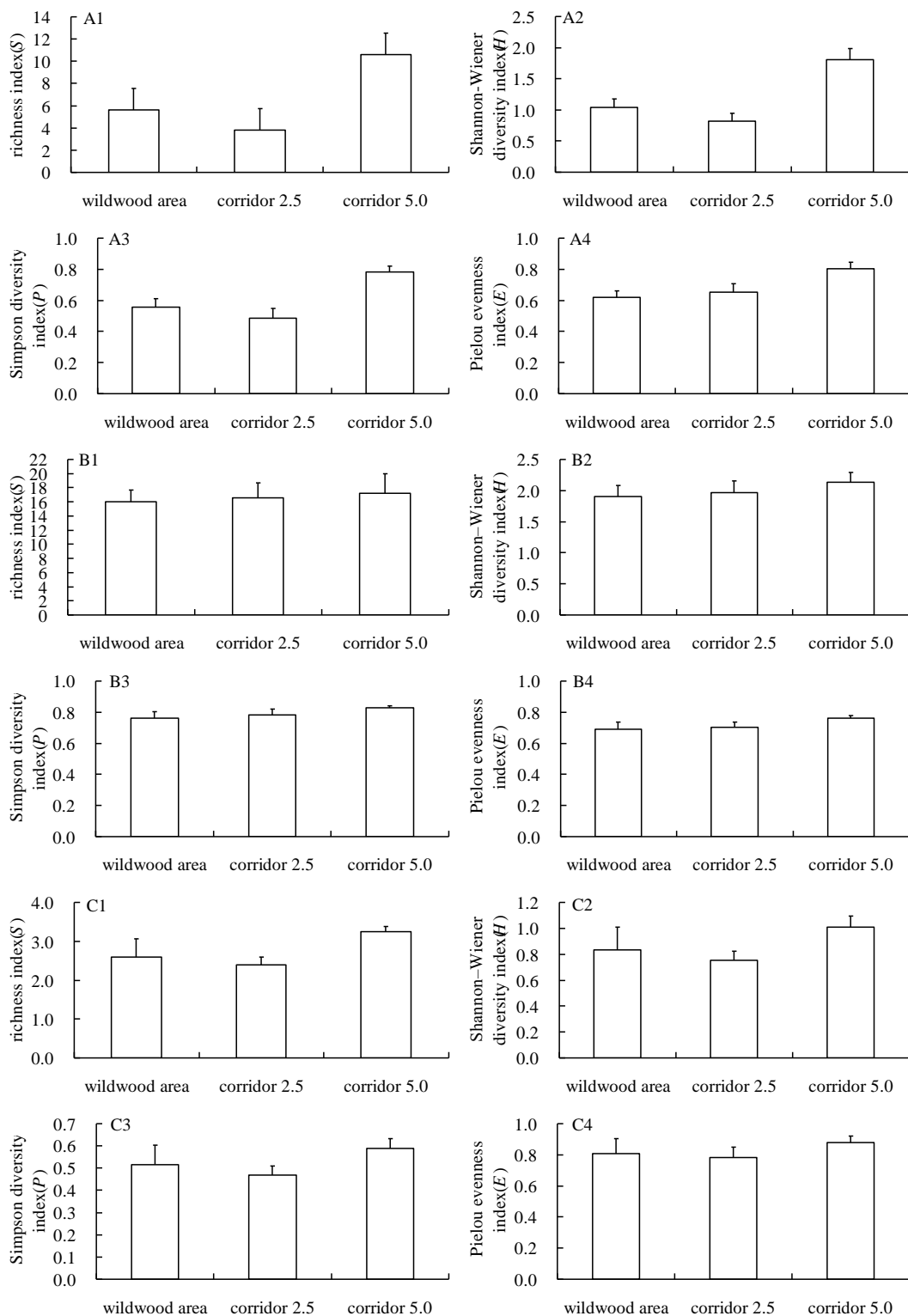
The species richness index, Shannon–Wiener diversity index, Simpson diversity index and Pielou evenness index of plant community in shrub layer are ranked as sample plot near 5.0 m scenic road corridor>sample plot near 2.5 m scenic road corridor>wildwood area (see *Fig. 1B1–1B4*).

The species richness index, Shannon–Wiener diversity index, Simpson diversity index and Pielou evenness index of plant community in herb layer are ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor (see *Fig. 1C1–1C4*).

Discussion

According to the investigation in Kunyu mountain national nature reserve of China, it can be known that compared with wildwood area, the mean DBH of tree layer decreases with the increase of width of scenic road corridor. The edge effect of shrub layer can be balanced by increasing the individual number of low-DBH shrubs and decreasing the number of high-DBH shrubs. Moreover, the edge effect of 2.5 m scenic road corridor than that of 5.0 m scenic road corridor.

In tree layer, the four indexes all showed as follows: sample plot near 5.0 m scenic road corridor was significantly higher than the sample plot near 2.5 m scenic road corridor and wildwood area.

Figure 1. *The richness index (1), Shannon-Wiener diversity index (2), Simpson diversity index (3) and Pielou evenness index (4) for the tree layer (A), shrub layer (B) and herb layer in wildwood area, sample plot near 2.5 m scenic road corridor and sample plot near 5.0 m scenic road corridor in Kunyu Mountain (average + standard error). Corridor 2.5: sample plot near 2.5 m scenic road corridor; corridor 5.0: sample plot near 5.0 m scenic road corridor*

In shrub layer, the four indexes abovementioned can be ranked as sample plot near 5.0 m scenic road corridor>sample plot near 2.5 m scenic road corridor>wildwood area. In herb layer, the four indexes can be ranked as sample plot near 5.0 m scenic road corridor>wildwood area>sample plot near 2.5 m scenic road corridor. This study shows that the upper trees in forest plant community of Kunyu Mountain are less sensitive to edge effect compared with understory plants, which is inconsistent with the results of study on *Cryptomeria fortunei* plantation in Zhougong mountain of Western Sichuan province (Wang et al., 2016).

Researches have shown that edge effect influences the richness and density of evergreen broad-leaf forest (Li et al., 2008), and forest edge effect is positive for extrinsic plant seed invasion (Lin and Cao, 2009). The influence of forest road on species diversity index only reaches into the plant community which is 5 m near road (Watkins et al., 2003), while a narrow corridor (< 4 m) will cause decrease of *Pinus koraiensis* growth level (Wang et al., 2003).

Conclusion

This study shows that two scenic road corridors (2.5 m and 5.0 m) have opposite effects on forest plant community in Kunyu Mountain of China. The 2.5 m scenic road corridor exerts an inhibition effect on the species composition and diversity of plants in Kunyu mountain national nature reserve, however, 5.0 m scenic road corridor has a promoting effect. We suggest that we can continue to study the two road corridors in Kunyu Mountain, especially the corridor width to study the physiological and biochemical indexes such as growth, development and reproduction of plants.

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