Front. Biol. China (2006) 2:163–167
DOI 10.1007/s 11515-006-0005-z

RESEARCH ARTICLE

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Studies on species diversity of *Larix chinensis* community ecotone

Abstract The communities of *Larix chinensis* and their ecotone in Qinling Mountains were investigated by sampling belt method. Species richness, Simpson diversity, Shannon-Weiner diversity, PIE and Pielou evenness indices of vascular plants in their communities and ecotone were calculated. Structure and composition of the communities in 6 sampling belts within the sites were analyzed. The results showed that the edge effect was obvious in the ecotone with a less changing environment (such as soil and terrain) and acute variation of composition and structure, while inconspicuous or even none in the ecotone with worse environmental condition (such as great space fluctuation). It is apparent that the edge effect of community was affected by soil and terrain, but not by microclimate.

Keywords Larix chinensis, community ecotone, species diversity

I Introduction

Community ecotone is commonly characterized by a group of given traits in time and space. The interactions between temporal and spatial characteristics usually occur in the boundaries between two or more landscape factors. Studies on ecotone have been focused on the early ecological pre-alarm and theoretic research and practice of ecological managements. Species diversity is an important index in characterizing a community. It is also very important in reflecting habit differences of plant community, the type of community structure, the stage of community succession and community stability. In a community ecotone formed by two or more different communities, significant edge effect usually appears, and it is very important on ecology and community to deeply study edge effect(Wang and Peng 1986). In recent years, many studies were conducted on the species composition of a community ecotone(Zhang and Skarpe 1996; Han 2000; Yu et al., 2000; Wang et al., 2000a b;Li 2001). However, only few studies on timber-line ecotone were carried out (Shi et al., 2000). The gradient variation on micro-habit in timber-line ecotone is very evident, whereas highly heterogeneous environment maintains high species diversity (Shi et al., 2000). By studying species diversity in timber-line ecotone, we can discover the distribution pattern of community structure and species diversity, thus further understanding the ecological processes in timber-line ecotone.

Larix chinensis belongs to the family of *Larix, pinacea,* an endemic plant species in China, and is distributed in sub-alpine Qinling Mountain with elevations of 2600~3500 m. These plants usually occur in headstreams and are the upper limit species of the forest. The community mainly formed by *Larix chinensis* is the dominant vegetation type in highly elevated areas of Qinling Mountain, an important water-maintained forest which plays an important role in maintaining water and soil, stabling mountain and improving ecology. In particular, *Larix chinensis* can thrive where other woods can not , showing its important role in nature. *Larix chinensis* has been regarded as the national second grade plant for protection because of its important role in species preservation, scientific research, ecological interest and economic role. In this paper, we studied the community of *Larix chinensis* in Qinling Mountain, the species composition and structure of its ecotone. The aims of our study are to discover variations of biological diversity in timber-line ecotone and provide theoretical basis for the sustained usage and conservation of the species.

Translated from *Guibaia*, 2005, 25 (2)[译自：广西植物，2005,25(2)]

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2 Study area

Taibai Mountain (107º41′23″~107º51′40″E, 33º49′31″~34º08′11″N) lies in the middle part of Qinling mountains, the climatic watershed in China. Topographty of Taibai

Mountain is characterized by very high mountain ranges with very steep north-facing slopes and gently inclined south-facing slopes. Vertical fall of the highest peak in Taibai Mountain ranges from 720 to 3 767 m. The study area lies in the west part of the humid plain of east China and east of Tibet plateau. Its climate lies on the south margin of temperate zone and north margin of semi-tropical zone. During winter, the study area is affected by the cold air coming from Mongolia, and during summer by subtropical high pressure zone the sub-tropic high-pressure. Because of the encounter of the south-north climate, the joint point of flora involved in Huabei, Huazhong and Huadong, China, is formed. In high mountains, water and heat conditions vary with increasing elevation. Vegetation landscape also shows significant vertical distribution, that is deciduous ork forests zone（780~2 300 m）, birch forest zone (2 300~2 800 m), conifer forest zone (2 800~3 400 m), and alpine shrub and meadow zones (above 3 400 m). *Larix chinensis* community mainly thrives in the alpine zone with an elevation more than 2 600 m, such as Guangtou Mountain and Niubei Mountain in Changan County, and Guangtou Mountain in Yang Xian County. The community is typically dense in the highest peak of Taibai Mountain. In this paper, we select the zone where *Larix chinensis* is dense to conduct our field survey.

3 Methods

3.1 Survey methods

Field survey was conducted last July 2003 in Taibai Mountain Natural Reserve with elevation ranging from 3 000 m to 3 500 m. We chose six sampling belts which stretched from *Larix chinensis* pure forest to mixed forest or forest edge. At the beginning of ecotone, each sampling belt approached to a pure forest of *Larix chinensis*. The width of the belts was 10 m, and their length 40~70 m. Within every 5 m along the belts, a 10 m × 10 m plot was made to measure some variables of the community, such as crown density, individual number of wood and diameter at the breast of wood. Five 2 m×2 m and five 1 m×1 m plots were made in each 10m × 10m plot to measure shrub and herb cover, and individual number of shrub and herb. Meanwhile the scientific names of all the species in the plots were recorded (Fig. 1).

3.2 Methods on biological diversity in community

We first calculated the dominance of wood, shrub and herb by using the following equation: dominance = relative density + relative cover. Then, we calculated community diversity indices, such as richness index, evenness index and species diversity index (Ma 1994a, b). Richness index is defined as the number of species in each plot, Shannon-Wiener index as $H' = -\sum Pi \ln Pi$, Simpson index as $D = 1-\sum Pi^2$, encounter probability as $PIE = \sum[(Ni / N)(N - Ni) / (N-1)]$, Pielou evenness index (*Jsw* and *Jsi*) as $Jsw = (1-\sum Pi \ln Pi) / \ln S$ and $Jsi = (1-\sum Pi^2) / (1-1/S)$.

In the above equations, *Pi* is the relative dominance, *Ni* the dominance of species *i*, *N* the summation of all the species dominance in the plot where species *i* appears, and S the summation of species number in the plot where species *i* appears.

4 Results and analysis

4.1 Structure and species composition of *Larix chinensis* community ecotone

According to our analysis on the data obtained from field survey, we found out that in *Larix chinensis* community ecotone, there were 78 vascular plants belonging to 68 Genera and 30 families including 10 *Compositaes*, 6 *Rosaceaes*, 6 *Umbelliffraes*, 5 *Ranunculaceaes*, 4 *Liliaceaes* and 4 *Graminaes*.

Based on the statistical analysis on the species composition of different communities and ecotones, the number of family, Genera and species increased from *Larix chinensis* pure forest to mixed forest. From pure forest to forest edge, the number of family, Genera and species increased in sampling belt 4, while in sampling belt 5, the number of species first decreased then increased. In addition, no significant variation on the number was found from pure forest to forest edge, and subsequently to shrub (Fig. 1).

The number of species gradually increased from *Larix chinensis* pure forest to mixed forest. In pure forest, only one wood species, *Larix chinensis*, was found. Wood cover ranges from 40% to 75% with shrub species including: *Lonicera taipeiensis*, *L. hispida*, *L. webbiana*, *Rosa omeiensis*, *Spiraea alpine*, *Ribes glaciale*, *Sabina pingii var. wilsonii*, *Rhododendron capitatum*, *Potentilla arbuscula var. veitchii*. Herb species were also abundant, such as *Carex lanceolata*, *C. capilliformis*, *Cardamine macrophylla*. In mixed forest, aside from *Larix chinensis*, there were also other woods, such as *Abies fargesii*, *Betula utilis*, *B. luminifera*, and some shrubs including *Rh. Clementinae*, *Sorbus tapashana*, *Rubus piluliferus* and *Lonicera taipeiensis*. Herb species in mixed forest were more abundant than those in the pure forest. The species number in pure forest was lower compared to those in mixed forest mainly because of the dense wood, high crown density, and lesser sunlight in undergrowth where relatively few shrubs and herbs appeared.

Table 1 Vascular flora of *Larix chinensis* communities and their ecotone

Sampling belt No.	Plot No.	Altitude/m	Crown density/%	Families	Genera	Species
1	1 Pure forest	3 140	40	10	12	15
	2 Mixed forest	3 135	30	13	15	18
	3 Mixed forest	3 135	20	13	14	17
	4 Mixed forest	3 120	10	16	31	24
	5 Mixed forest	3 100	25	12	15	18
2	1 Pure forest	3 150	75	15	22	24
	2 Mixed forest	3 140	30	18	24	28
	3 Mixed forest	3 130	65	17	21	22
	4 Mixed forest	3 125	75	16	21	25
3	1 Pure forest	3 130	55	15	16	20
	2 Mixed forest	3 135	45	17	24	27
	3 Mixed forest	3 140	55	17	25	34
4	1 Pure forest	3 370	40	10	13	11
	2 Pure forest	3 380	40	12	14	14
	3 Forest edge	3 380	30	16	19	22
5	1 Pure forest	3 245	55	11	13	14
	2 Pure forest	3 260	60	8	10	11
	3 Forest edge	3 260	40	9	12	13
6	1 Pure forest	3 340	40	17	18	20
	2 Forest edge	3 345	70	11	14	19
	3 Shrub	3 350	15	10	13	17

In sampling belt 4, the number of species gradually increased from *Larix chinensis* pure forest to forest edge. In sampling belt 5, the number of species first increased then subsequently decreased, with its peak occurring in the center of pure forest (plot 2), the lowest 5 m away from the center (plot 3), and intermediate in the forest edge (plot 1). In both pure forest and forest edge, the wood species was only *Larix chinensis*, which covers 30%~60% of the area. In sampling belt 4, the shrubs in pure forest included *Rhododendron concinuum*, *Potentilla arbuscula var. veitchii*, *Lonicera taipeiensis* and *L. webbiana*, while shrubs in the forest edge includes *Rhododendron capitatum* and *Potentilla arbuscula* var. *veitchii*. There were 13 more species in the forest edge than that in the pure forest, which include species such as *Carex capilliformis*, *Oxalis corniculata*, *Pedicularis davidii* and *Phlomis megalantha*. The special environment, such as abundant sunlight, is helpful for the survival of plants. As a result, the total number of species in forest edge was high. In sampling belt 5, the shrubs in pure forest included *Lonicera webbiana*, *Rhododendron capitatum*, *Sabina pingii var. wilsonii* and *Salix cupularis*, while in forest edge, *Sabina pingii var. wilsonii* disappeared. The herbs species in pure forest had *Pedicularis decora*, *Anemone taipaiensis* and *Phlomis megalantha*, but in plot 2 *Glechoma longituba* and *lepisorus eilophyllus* disappeared. The high wood cover in plot 2 caused the shrubs and herbs species to be low as well as the total species number. The species number in plot 3 was lower than those in plot 1 possibly because forest edge (plot 3) is close to rock where soil is sterile, the percentage of rock is high (about 60%), and environment is sordid. As a result of the non optimal habitat,conditions, species number decreased.

Species number gradually decreased from *Larix chinensis* pure forest to forest edge, then to shrubs. *Larix chinensis* was the only wood species and it covers 40%~70% of the area. In pure forest, *Rhododendron capitatum*, *Potentilla arbuscula* var. *veitchii* and *Lonicera hispida* were present. In forest edge, there were *Salix cupularis* and *Rhododendron capitatum*, in addition to the three species mentioned. In pure forest, herbs species included *Rubia cordifolia*, *Glechoma longituba* and *Phlomis megalantha*. Although sunlight condition in forest edge was better compared to the pure forest its wood cover was high reaching up to 70%, which decreased the species number of shrubs and herbs. In shrubs, although wood cover was low (only 15%), *Rhododendron capitatum* covered 55% of the area. The high shrub cover resulted to low species number of herbs and low total species number.

The above results showed that species number in mixed forest and some forest edge was relatively high. To a great degree, the development of vegetation was determined by environmental conditions with special spatial position. Because *Larix chinensis* is usually found in highly elevated areas, in addition to the relatively great difference in its habitat, difference in plant species number of plant communities occurred.

4.2 Species diversity in *Larix chinensis* community and ecotone

Species diversity of *Larix chinensis* also showed variations, because of the different environments, structures and

species compositions in the *Larix chinensis* community ecotone (Table 2).

From *Larix chinensis* pure forest to mixed forest, species variations gradually increased. Simpson index, Shannon index, intra-encounter index and Pielou index showed similar variations. Because of the dense wood, high crown density and slight sunlight in the undergrowth found in pure forest, species number, coverage and diversity index of shrubs and herbs were low. However, crown density in wood canopy was low and sunlight in undergrowth was relatively plenty, which resulted in a high number of shrub and herb species, high individual number for both, and high cover and diversity indices. In addition, it was shown that different community types, different areas, and same area with different communities had different species diversities (Table 2). In sampling belt 3, the diversity index of mixed forest was the highest. Its species richness was 34, Simpson index 2.2, Shannon index 4.75, and intra-encounter index 4.4. This can be attributed to the better composition of sunlight, water, etc.

Table 2 Diversity indices of *Larix chinensis* communities and their ecotone

Plot No.	*S*	*D*	*H'*	*PIE*	*Jsi*	*Jsw*
1	15	1.13	2.50	2.26	1.32	1.28
2	18	1.25	2.51	2.51	1.63	1.59
3	17	1.79	3.38	3.58	2.37	2.29
4	24	2.09	4.41	4.17	2.58	2.40
5	18	2.07	4.18	4.15	2.67	2.57
1	24	1.38	2.90	2.76	1.01	1.42
2	28	1.74	3.59	3.49	2.27	2.09
3	22	1.78	3.73	3.56	2.22	2.15
4	25	1.86	4.06	3.72	2.24	2.15
1	20	1.36	2.82	2.72	1.61	1.42
2	27	1.58	3.34	3.15	2.02	1.96
3	34	2.20	4.75	4.40	2.55	2.27
1	11	0.96	1.93	1.91	1.18	1.16
2	14	1.09	2.52	2.18	1.32	1.36
3	22	0.96	2.36	1.92	1.19	1.17
1	14	1.44	2.92	2.88	1.84	1.75
2	11	1.26	2.09	2.06	1.78	1.57
3	13	1.21	2.32	2.42	1.76	1.67
1	20	0.85	2.07	1.70	0.97	0.93
2	19	1.55	3.49	3.10	1.84	1.75
3	17	0.97	2.33	1.93	1.10	1.06

Note: sample plot no. was the same as that in Table 1

From *Larix chinensis* pure forest to forest edge, the species richness in sampling belt 4 gradually increased. Simpson index, Shannon index, intra-encounter index and Pielou index first increased, and subsequently decreased. This can be attributed to the abundant sunlight which was helpful for the survival of sun plant. As a result, the species number in forest edge was higher than that in pure forest. Because forest edge is close to subalpine meadow and the corrosion relics of Glacier Period in Quaternary Period, the soil in this area is dry, variation of topographty obvious, species number and vegetation cover low, which made Simpson index, Shannon index, intra-encounter index and Pielou index low. However, in sampling belt 5, species richness, Shannon index, Pielou index (*Jsi*) and intra-encounter index first decreased, then increased. Simpson index and Pielou index (*Jsw*) gradually decreased, but species diversity in forest edge was lower than that in pure forest. The reason can possibly be attributed to the implication that wood cover and undergrowth sunlight in plot 2 was higher and lower, which caused fewer shrub and herb species, lower shrub and herb cover and lower diversity index. Because the outside of forest edge is close to rock, the soil here is arid. As a result, the species, species number, cover and diversity index were all relatively low.

From *Larix chinensis* pure forest to forest edge and to shrubs, species richness gradually decreased. Simpson index, intra-encounter index and Pielou index first increased and then decreased, shewing that the species diversity in forest edge was the highest. Species diversity in forest edge was higher than that in pure forest and shrubs, which was possibly caused by edge effect.

5 Discussion

In *Larix chinensis* pure forest and mixed forest, species diversity is higher in mixed than in pure forest. The main reason is that wood cover of community ecotone in mixed forest is relatively low. Such environment with moderate sunlight is optimal habitat for the survival of sun and shade plants. However, wood cover in pure forest is relatively high causing a shady environment, an optimal habitat condition for shade plants. Because the intensity of sunlight affects the survival and development of plants, it is obvious that sun shrubs would have alesser chances of thriving since minimal sunlight is available. Eventhough sun plants could survive in such habitat, their development is slow. As a result, shrubs in such environment are sparse and shrub cover is low. On the other hand, the sunlight in herbs is relatively strong, which causes relatively dense herbs, high herb cover and high species diversity of the whole community. So, we deduced that woods, shrubs and herbs in community inter-react and inter-affect, which can be supported by other studies (Yu et al., 1999).

No significant variation was found on species diversity between *Larix chinensis* pure forest and forest edge, which means that edge effect is not significant ,or does not exist in rigorous environment (significant spatial fluctuation). The community composition is affected not only by climate but also by other ecological factors, such as the soil (Gao 1994). Climate environment plays an important role in affecting species diversity in ecological ecotone areas. For fundamental elements, the effect of climate is homogenous in large scale, but local geographical condition and the variation of environmental fundamental elements can cause the formation of all kinds of small ecological patterns in relatively homogenous atmosphere environment (Gao 1994). So, in hetergenous environment, and from the center of the community to the edge of ecotone, the distribution of some species is gradually limited on some of the fundamental environmental elements (topographty, physiognomy, soil).

In sampling belt 4, because forest edge is close to herbs and small rock river (faultage mountain by Galcier Period of Tertiary Period), the soil around the belt is sterile and the topographty variation is apparent, causing the decrease in species diversity. In sampling belt 5, species diversity is lower than that in pure forest, which can be possibly attributed to the large square of bare rock (60%). In such environment, the soil optimal for plant development is lacking. Moreover, the outside of the forest edge is close to rocks (faultage mountain by Galcier Period of Tertiary Period) where the soil is very sterile. All the above reasons may have caused the lower species diversity in forest edge.

Among *Larix chinensis* pure forest, forest edge and shrubs, maximum species diversity occurred in forest edge. Thus, we can make a conclusion that ecological ecotone, with acute variation in hiberarchy, appears to have a significant edge effect, which was also proven by previous studies (Gao 1994; Wang et al., 2000; Wang and Lei 2002). From the viewpoint of biological composition, forest edge, close to shrubs, includes the components of two close communities, such as *Salix cupularis* and *Phlomis megalantha*. Meanwhile, the special environment in ecotone causes the formation of endemic species. As a result, plant species and community structures are commonly more complicated.

Acknowledgement This paper was supported by the National Natural Science Foundation of China (No. 30070083).

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