Jour. Korean For. Soc. Vol. 99, No. 5, pp. 720~725 (2010)

JOURNAL OF KOREAN FOREST SOCIETY

Spatial Pattern of *Larix gmelini* in a Spruce-fir Valley Forest of Xiaoxing`an Mountains, China

Guangze Jin[1], Liang Liu[1], Zhili Liu[1] and Ji Hong Kim[2*]

[1]*School of Forestry, Northeast Forestry University, Harbin, 150040, China*

[2]*College of Forest & Environmental Sciences, Kangwon National University, Chuncheon 200-701, Korea*

Abstract : On the basis of vegetation data in the 9.12 ha (380 m × 240 m) permanent sample plot of the spruce-fir valley forest in Liangshui National Reserve of Xiaoxing`an Mountains, the study was conducted to evaluate spatial distribution pattern and spatial association by using point pattern analysis for living and dead trees of *Larix gmelini* by DBH size class. The number of *L. gmelini* were counted as 59 living stems/ha (6.42 m^2/ha of basal area) and 34 dead stems/ha (2.86 m^2/ha of basal area). The distributional curve of diameter class exhibited bimodal shape. The analysis of spatial distribution patterns of all living larch stems noted the clumped distribution on the whole. The size of larch aggregates of dead stems was decreased as diameter class was increased. The distribution of dead stems became gradually randomized with decreased clumped size as the scale increased. Living stems and dead stems of the larch had positive spatial association at most of scales, illustrating that the occurrence of mortality of the larch tree was closely related to the distribution pattern of living larch trees.

Key words **:** *dead stem distribution, large permanent sample plot, O-ring statistics, point pattern analysis, spatial association*

Introduction

The spatial distribution pattern of a population is the consequence of integrative processes associated with the eco-physiological characteristics of the population, intra-specific and inter-specific relationship, and environmental conditions (Greig-Smith, 1983). Dale (1999) emphasized importance of spatial distribution of individuals in a species, playing major role in plant ecological theory. Condit *et al.* (2000) have been assembling a long-term, large-scale, and global research effort on spatial patterns and dynamics of forest ecosystems.

Larix gmelini has been naturally distributed in far eastern Siberia of Russia, and Daxingan mountains, Xiaoxingan mountains, and Zhangguangcai mountains beyond 42°30' north latitude in China (Zhou, 1986). The *L. gmelini* forests have extended in the area of around 3,300,000 ha and the growing stock of the forests has been estimated more than 300,000,000 m^3 (Li, 1993), occupied 8% of total forest carbon storage and 30% of timber production in China (Zhou *et al*., 2000).

Numbers of scientific studies for *L. gmelini* have been carried out on account of ecological importance in China (Xu, 1998). Of these several researches have been reported on the spatial distribution pattern of *L. gmelini* individuals mainly growing throughout Daxingan Mountains. Xu *et al.* (1994) analyzed different age structure of the species by using the analytical method of spatial distribution pattern proposed by Greig-Smith (1983). Han (1994) investigated regeneration pattern on the size of 2 m × 2 m and Ban *et al.* (1997) reviewed the affect of spatial distribution on the mortality and reproduction patterns. A few of dimensional analyses were examined for spatial distribution pattern of *L. gmelini*, such researches as Ma *et al.* (1999) on correlation dimension, Ma and Zu (2000a) on information dimension, and Ma and Zu (2000b) on box-counting dimension. Shu *et al.* (2008) implemented quantitative study of spatial distribution pattern by the analysis of correlation between mean and variance, index of dispersion, and index of clumping for *L. gmelini* trees greater than 5 cm of DBH in two 50 m × 50 m sample plots each of the primitive forest, successive cutting forest, and clearcutting forest. Nevertheless, since most of previous studies concerning the spatial distribution pattern have been subjected to restriction on the size of sample plot and survey method, they were hardly capable of explaining the larger and broader scale of spatial

*Corresponding author
E-mail: kimjh@kangwon.ac.kr

distribution pattern for the species.

On the basis of vegetation data in permanent sample plot of 380 m × 240 m in Liangshui National Reserve of Xiaoxing`an Mountains, this study was carried out to evaluate spatial distribution pattern and spatial association by using point pattern analysis for living and dead trees of *L. gmelini* by DBH size class in the spruce-fir valley forest type. This study could provide the fundamental information for the occurrence, mortality, and regeneration capacity of the *L. gmelini* in the Northeast China.

Materials and Methods

1. Study area

The study was conducted in the spruce-fir valley forest, located in Liangshui National Reserve of Xiaoxing`an Mountains (Figure 1). The reserve is characterized by rolling mountainous terrain with 707.4 m of highest peak above sea level and 300 m of lowest peak above sea level, and average slope gradient is 10-15°. Mean annual temperature is -0.3°C with mean annual highest temperature of 7.5°C and lowest temperature of -6.6°C. Mean annual precipitation is 676 mm with 78% of relative humidity and 805 mm of evaporation rate (Jin *et al.*, 2009).

The trees of *L. gmelini* growing in the spruce-fir valley forest of Liangshui National Reserve are distributed along the southern boundary of Xiaoxing`an Mountains, of which the distribution range would be located in the sensitive areas to the climate change. This susceptible forest ecosystems have been confronted with the change of growing conditions, especially due to the thawing of permafrost by global warming. In 2006 the permanent sample plot of 380 m × 240 m was established to monitor the effects of climate change on the structure and function of the spruce-fir valley forest.

The vegetation types of Liangshui National Reserve are classified into the mixed *Pinus koraiensis*-broadleaved forest type above 300 m sea level, and types of spruce-fir forest, *Alnus hirsuta* forest, and *Salix revarine* forest below 300 m sea level in valleys. The spruce-fir valley forest type is distributed on permafrost in patches characterized by cold and moist site condition. Dominated by *Picea koraiensis* and *Abies nephrolepis*, the type is commonly composed of *Larix gmelini*, *Betula platyphylla*, *Betula costata*, *Acer ukurunduense*, *Acer mono*, *Prunus padus*, *Acer tegmentosum*, and *Alnus sibirica* (Jin *et al.*, 2009).

2. Data collection and analysis

The vegetation data were collected from the 380 m × 240 m rectangular permanent experimental plot established in the spruce-fir valley forest in 2006. The plot was divided into nine hundred twelve 10 m × 10 m square sub-plots of which four corners were marked with driving stakes. For every woody plant greater than 2 cm of DBH in each sub-plot, we attached the aluminum number tag, placed coordinates on the grid map, measured DBH and height, and recorded existing type of dead stems.

All *L. gmelini* individuals of DBH ≥ 2 cm in 9.12 ha plot of the spruce-fir valley forest were subjected to dividing into three DBH size classes, trees of 2 cm ≤ DBH < 10 cm, 10 cm ≤ DBH < 40 cm, and DBH ≥ 40 cm (Figure 2). The spatial distribution pattern and spatial association were analyzed by the univariate *O*-ring statistic and bivariate *O*-ring statistic, respectively, for all living and dead stems of each DBH size class. We used Programita software devised by Wiegand and Moloney (2004). The analysis was implemented 99 times of Monte

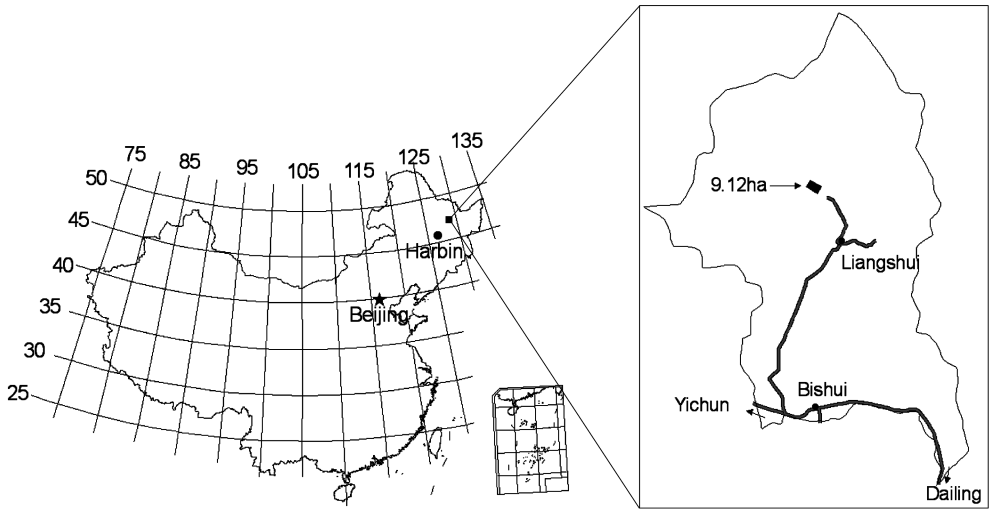

Figure 1. Location of the study area.

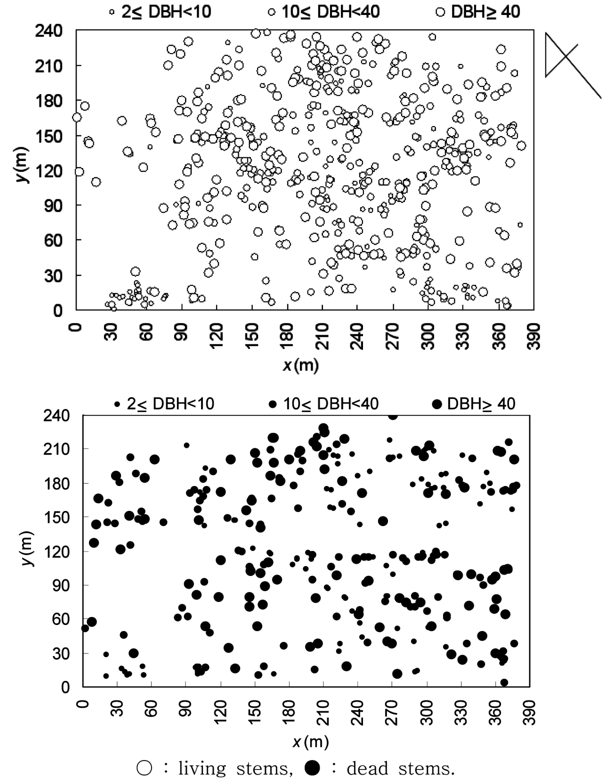

Figure 2. Position maps of living and dead stems of *Larix gmelini* in the 9.12 ha sample plot.

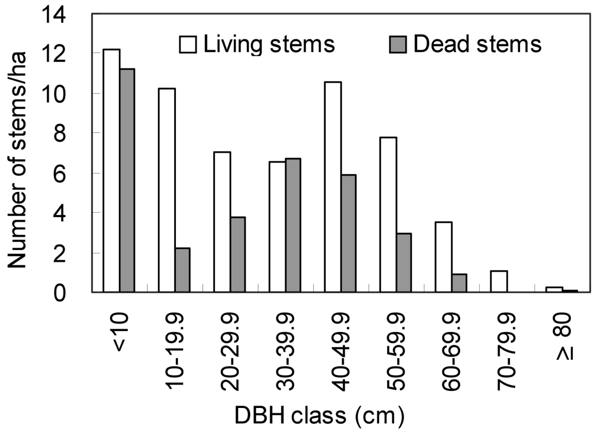

Figure 3. DBH class distribution of *Larix gmelini* in the spruce-fir valley forest.

Carlo simulation and obtain 99% of confidence interval for spatial scale of 1~120 m (Wiegand and Moloney, 2004).

In the univariate *O*-ring statistics, if the value of *O*(r) is greater than the upper limit of confidence interval, the target species is supposed to be distributed as clumped pattern, if within the confidence interval as random pattern, and if less than lower limit of confidential interval as regular pattern. In the bivariate *O*-ring statistics, if the value of *O*(r) is greater than the upper limit of confidence interval, the target pair has positive association at the corresponding scale, if within the confidence interval as no significant association, and if less than lower limit of confidence interval as negative association.

Results

1. Population structure of *Larix gmelini*

The number of *L. gmelini* individuals in the spruce-fir valley forest were counted as 63 stems per hectare for seedlings ($H \geq 0.3$ m & $DBH < 2$ cm), 59 living stems ($DBH \geq 2$ cm) per hectare, and 34 dead stems ($DBH \geq 2$ cm) per hectare (Table 1). The average basal area per hectare of the living stem was estimated to 6.42 m^2 with mean DBH of 31.2 cm. The mean basal area and mean DBH of dead stems were 2.86 m^2 and 26.9 cm, respectively. The result showed smaller diameter for dead stems than living ones, possibly indicating that natural thinning of the species had been taking place in the dense spruce-fir valley forest, supporting improved growing space for survived larches.

Overall diameter distribution of *L. gmelini* presented bimodal shape in both living and dead stems, relatively large number of dead stems on diameter < 10 cm and 30~50 cm (Figure 3). The pattern of diameter distribution of living stems showed little difference between small and large diameter classes. However, it could be recognized that low density and high mortality of small diameter class (< 10 cm) stems would notify the shortage of regeneration replenishment, indicating that the larch would decline in population size.

The existing types of dead stems in the order of large proportion were breakage at trunk, uprooted blow-down, standing die, breakage at rootstock, and stump, showing varied proportion in the size of diameter class (Table 2). The proportional values of types of standing die and uprooted blow-down were relatively high in DBH < 10 cm, probably due to dying of overtopped younger larch

Table 1. Stand structure of *Larix gmelini* in the spruce-fir valley forest.

	Density (stems/ha)	Basal area (m^2/ha)	DBH (cm)	
			Mean ± SD	Max.
Seedlings ($H \geq 0.3$ m & $DBH < 2$ cm)	63.0			
Living stems ($DBH \geq 2$ cm)	59.1	6.42	31.2 ± 20.29	110
Dead stems ($DBH \geq 2$ cm)	33.7	2.86	26.9 ± 18.87	86

Table 2. Relative density of existing types of *Larix gmelini* dead stems by DBH classes in the 9.12 ha sample plot of the spruce-fir valley forest.

DBH class (cm)	Uprooted blow-down	Breakage at rootstock	Breakage at trunk	Stump	Standing die
< 10	33.7	12.9	14.9	4.0	34.7
10-19.9	9.5	23.8	33.3	9.5	23.8
20-29.9	26.5	17.6	41.2	5.9	8.8
30-39.9	15.3	13.6	52.5	10.2	8.5
40-49.9	16.4	18.2	49.1	7.3	9.1
50-59.9	3.7	11.1	55.6	11.1	18.5
60-69.9	0.0	11.1	44.4	11.1	33.3
70-79.9	0.0	0.0	0.0	0.0	0.0
≥ 80	0.0	0.0	100.0	0.0	0.0
Total	20.8	15.0	37.1	7.2	19.9

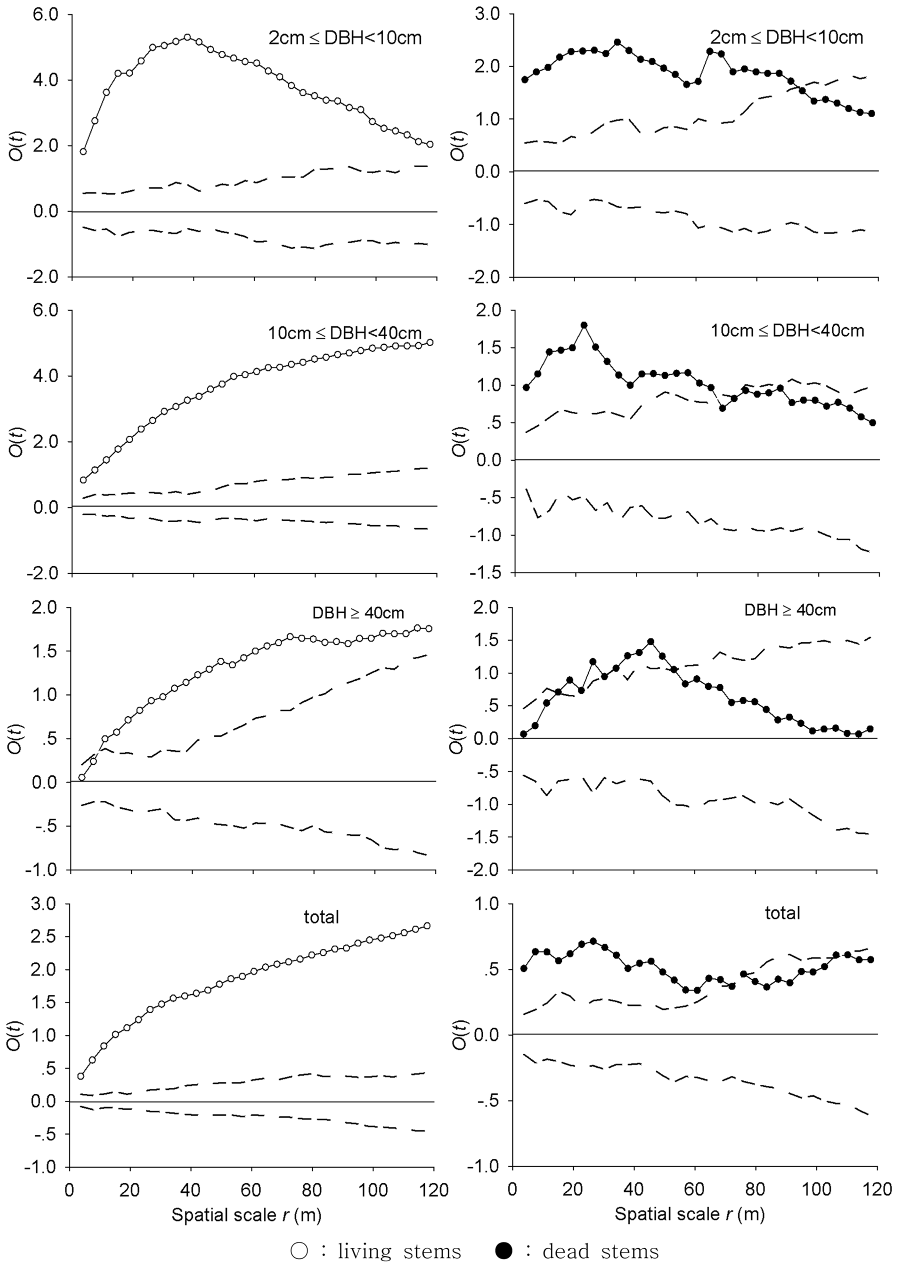

Figure 4. Spatial distribution patterns of *Larix gmelini* in the 9.12 ha sample plot of the spruce-fir valley forest.

trees by the competition of limited light coming through the stand and due to being uprooted down on the forest floor by stroke of falling snags. The type of breakage at trunk was highest proportion in the other diameter classes ≥ 10 cm (Table 2), mainly because hard wind break trunks of the living and dead larch stems at the canopy.

2. Spatial patterns of *Larix gmelini*

The analysis of spatial distribution patterns of all living larch stems of DBH ≥ 2 cm noted the clumped distribution on the whole at all scales less than 120 m. Even though the random distribution pattern was detected at less than 10 m scale for both living and dead larch stems of DBH ≥ 40 cm, stems of the other DBH size classes showed the clumped distribution pattern at all scales less than 120 m (Figure 4). The intensity of clumped distribution pattern was highest at the scale of 38 m for living larch stems of 2 cm ≤ DBH < 10 cm, presenting an bimodal shape curve. On the other hand, as scale was increased, the intensity was gradually increased for living larch stems of ≥ 10 cm. All dead stems of DBH ≥ 2 cm generally showed clumped distribution pattern at less than 90 m scale, and random distribution pattern at more than 90 m scale. The dead stem sizes of 2 cm ≤ DBH < 10 cm, 10 cm ≤ DBH < 40 cm, and DBH ≥ 40 cm commonly exhibited clumped distribution pattern at the scales < 95 m, < 68 m, and < 53 m, respectively, but random distribution at the other scales, indicating that, as diameter classes were increased, the scale of clumped distribution pattern was decreased (Figure 4).

3. Spatial association of living and dead stems of *Larix gmelini*

All living and dead larch stems of DBH ≥ 2 cm had positive spatial association on the whole at all scales less than 120 m. The analytical result of each DBH size class showed that the stems of 2 cm ≤ DBH < 10 cm had positive spatial association with each other at all scales less than 120 m. The stems of 10 cm ≤ DBH < 40 cm at < 7.6 m and > 91 m and of DBH ≥ 40 cm at < 7.6 m and > 110 m had the positive association, but the association was not significant at the other scales for 10 cm ≤ DBH < 40 cm and DBH ≥ 40 cm (Figure 5).

Discussion

The results of stand structure of *Larix gmelini* in the spruce-fir valley forest of Liangshui National Reserve of Xiaoxing`an Mountains were similar to the stand more than 160 years old in main distributional range of the species in terms of average diameter, but recorded one sixth basal area, compared with study done by Li (1993). The distributional curve of diameter class exhibited bimodal shape. Relatively high ratio of mortality and low ratio of regeneration replenishment of the larch (Figure 3) intimated that the larch was probably replaced by other tree species in the studied forest.

The clumped distribution pattern might be known as common phenomenon in regenerated stands (van Laar and Akca, 1997). In our 380 m × 240 m sample plot, living stems of the larch 2 cm ≤ DBH < 10 cm and 10 cm

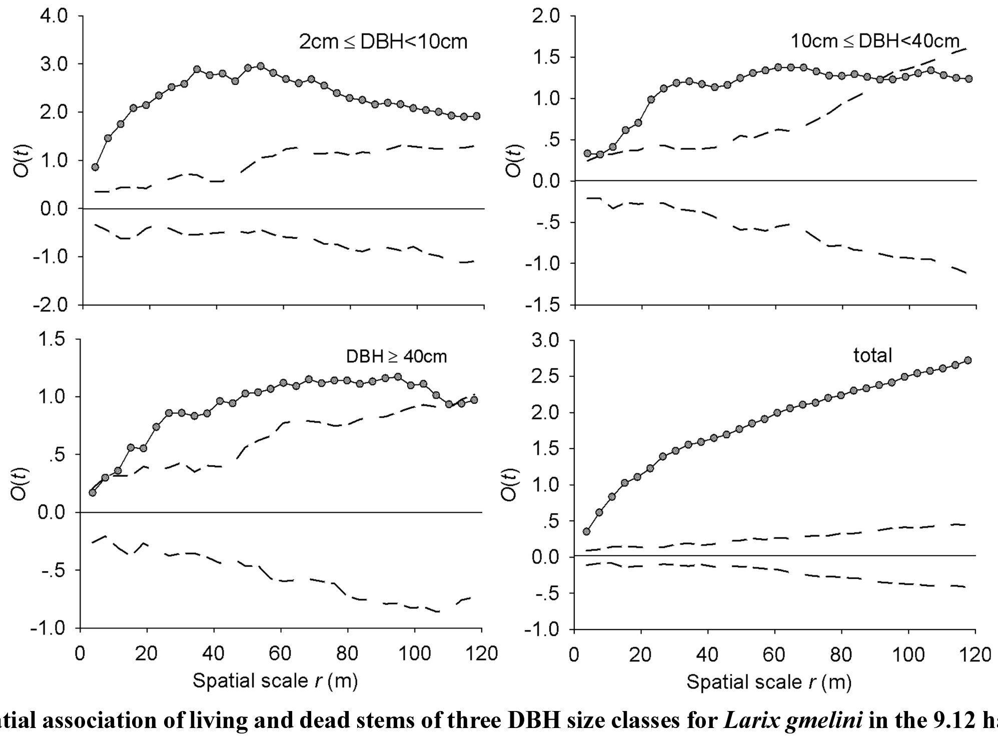

Figure 5. Spatial association of living and dead stems of three DBH size classes for *Larix gmelini* in the 9.12 ha sample plot of the spruce-fir valley forest.

≤ DBH < 40 cm presented clumped distribution pattern at all scales within 120 m which was largest scale of analytical process. The distinctive feature of clumped distribution pattern was also observed in forests of Daxingan Mountains (Xu, 1998). This may react upon an important ecological strategy for maintaining the *L. gmelini* population to take advantage of forming favorable micro-environment for survival and growth of seedlings and saplings (Han, 1994). Large diameter living larch trees (DBH ≥ 40 cm) displayed clumped distribution at more than 10 m scale but random distribution at less than 10 m scale. Random distribution at smaller scale was seemed to be the result of competition from the growth of larch trees, of which expanded crown obtained better growing space so as to be advantageous to grasp larger amount of sunlight (Ishizuka, 1984). The size of clumped mass of dead stems was decreased as diameter class was increased (Figure 4). The fact illustrated gradually becoming random distribution by occurring dead stems and decreasing clumping size.

All living and dead larch stems of DBH ≥ 2 cm had positive spatial association on the whole at all scales less than 120 m which was largest scale of analytical process. In every DBH size class, living and dead stems had positive spatial association at middle portion of scales. Living stems and dead stems of the larch had positive spatial association in most of scales, illustrating that the occurrence of mortality of the larch tree was closely related to the distribution pattern of living larch trees.

The trees of *L. gmelini* growing in the spruce-fir valley forest of Liangshui National Reserve are distributed along the southern boundary of Xiaoxing`an Mountains, of which the distribution range would be located in the sensitive areas to the climate change. Accordingly, the investigation of spatial distribution pattern and continuous monitoring of *L. gmelini* in this region could provide important information to predict the influence and side effect of climate change on the dynamics of larch population in the spruce-fir valley forest.

Acknowledgements

The research was supported by the Forestry Science and Technology Supporting Program of China (No.2006BAD03A0702), and Forestry Commonweal Science and Technology Project of China (No.200704005, No.200804001).

Literature Cited

1. Ban, Y., Xu, H.C. and Li, Z.D. 1997. Mortality patterns of *Larix gmelini* and effect of fallen dead wood on regeneration of old *Larix gmelini* forest. Chinese Journal of Applied Ecology, 8(5): 449-454.
2. Condit, R., Ashton, P.S. and Baker, P. 2000. Spatial patterns in the distribution of tropical tree species. Science 288: 1414-1418.
3. Dale, M.R.T. 1999. Spatial Patterns Analysis in Plant Ecology. Cambridge University Press, Cambridge.
4. Greig-Smith, P. 1983. Quantitative Plant Ecology. Blackwell Scientific Publications. 3rd Edition. London, UK. pp. 21-36.
5. Han, M.Z. 1994. A study on the patterns of natural regeneration and ecological strategy of dahurian larch population. Journal of Inner Mongolia Forestry College 16(1): 1-10.
6. Ishizuka, M. 1984. Spatial pattern of trees and their crowns in natural mixed forests. Japanese Journal of Ecology 34: 421-430.
7. Jin, G.Z., Liu, Z.L. and Cai, H.Y. 2009. Coarse Woody Debris (CWD) in a Spruce-fir Valley Forest in Xiaoxingan Mountains, China. Journal of Natural Resources 24(7): 1256-1266.
8. Li, J.W. 1993. Coniferous Forest. 113-149, In The Forest of Heilongjiang. Editorial Board of the Forest of Heilongjiang. Northeast Forestry University Press and China Forest Publishing House.
9. Ma, K.M., Zu, Y.G. and Ni, H.W. 1999. Fractal properties of the spatial pattern of *Larix gmelini* population: correlation dimension. Acta Ecologica Sinica 1999(3): 353-358.
10. Ma, K.M. and Zu, Y.G. 2000a. Fractal properties of the spatial pattern of *Larix gmelini* population-information dimension. Acta Ecologica Sinica 20(2): 187-192.
11. Ma, K.M. and Zu, Y.G. 2000b. Fractal properties of the spatial pattern of *Larix gmelini* population: box-counting dimension. Bulletin of Botanical Research 20(1): 104-111.
12. Shu, M., Tie, N., Xi, Q.H. and Liu, W.J. 2008. Study on the spatial distribution pattern of *Larix gmelini* forest. Forest Resources Management 3: 86-89.
13. van Laar, A. and Akca, A. 1997. Forest Mensuration. Cuvillier Verlag, Goettingen, Germany, 418pp.
14. Wiegand, T. and Moloney, K.A. 2004. Rings, circles and null-models for point pattern analysis in ecology. Oikos 104: 209-229.
15. Xu, H.C., Fan, Z.F. and Wang, S. 1994. A study in spatial patternsernsernserin virgin *Larix gmelini* forest. Acta Ecologica Sinica, 14(2): 155-160.
16. Xu, H.C. 1998. Da Hinggan Ling Mountains Forest in China. Science Press: Beijing. 231.
17. Zhou, Y.B., Yu, Z.L. and Zhao, S.D. 2000. Carbon storage and budget of major chinese forest types. Acta Phytoecologica Sinica, 24(5): 518-522.
18. Zhou, Y.L. 1986. Ligneous Flora of Heilongjiang. Heilongjiang Science Press. Harbin. 585pp.

(Received July 16, 2010; Accepted September 26, 2010)