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Spatial Distribution Pattern of *Chloranthus japonicus* Population at Mt. Ahop

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The patchiness of local environments within a habitat is assumed to be a primary factor affecting the spatial patterns of plants, and a randomization procedure is developed for testing the null hypothesis that only spatial association with patches determined the spatial patterns of plants. *Chloranthus japonicus* (Chloranthaceae) is an herbaceous perennial and a member of the genus *Chloranthus* in the family Chloranthaceae. The spatial pattern of *C. japonicus* was analyzed according to several patchiness indices, population uniformity or aggregation under different sizes of plots by dispersion indices, and spatial autocorrelation. Population densities (D) varied from 0.356 to 2.270, with a mean of 1.527. The values of dispersion indices (at Mt. Ahop were lower than 1 at six plots (2 m × 2 m, 2 m × 4 m, 4 m × 4 m, 4 m × 8 m, 8 m × 8 m, and 8 m × 16 m), but the two large plots (16 m × 16 m and 16 m × 32 m) were higher than 1. Thus, the aggregation indices (were negative at Mt. Ahop, which indicates a uniform distribution. The two large plots (16 m × 16 m and 16 m × 32 m) had positive CIs. However, the values were not large (0.009 for the 16 m × 16 m plot and 0.038 for the 16 m × 32 m plot). The mean crowding (*M**) and patchiness index (*PAI*) showed positive values for all plots.

Key words : *Chloranthus japonicus,* Mt. Ahop, mean crowding, patchiness index, spatial distribution

Introduction

Spatial distribution pattern of suitable environments for plants is often patchily structured at various sizes within the habitat, like islands in a sea [10]. The word "structure" comes from Latin struere which means to build, to arrange, and contains the notion of an organized thing. Performances of individual plants in response to the patchiness of environments are spatially non-random processes [19], such as density-independent mortality [2], patchy establishment of seedlings [4] and seed dispersal patterns within and between patches [18].

Spatial structures exist, because geographical space is not constituted by a set of unique places, occupying random locations. A spatial structure is completely described only if, beyond the form taken by the arrangement of objects, it is possible to figure out the inter-dependencies among the latter. Spatial structuring is an essential community and ecosystem property [20]. Understanding the underlying causes of community composition and its spatial variation (E-diversity) remains a major goal in community ecology [8, 12].

Species distribution is not to be confused with dispersal, which is the movement of individuals away from their area of origin or from centers of high on density. Dispersion or distribution patterns show the spatial relationship between members of a population within a habitat. Individuals of a population can be distributed in one of three basic patterns: uniform, random, or clumped. In a uniform distribution, individuals are equally spaced apart, as seen in negative allelopathy where chemicals kill off plants surrounding sages. In a random distribution, individuals are spaced at unpredictable distances from each other, as seen among plants that have wind-dispersed seeds. In a clumped distribution, individuals are grouped together, as seen among elephants at a watering hole.

Chloranthus japonicus Siebold is a perennial plants and genus is *Chloranthus* in the family Chloranthaceae. The Chloranthaceae is a small family with five genera and around seventy species occurring in tropical America, East Asia and the Pacific [13]. *C. japonicus* is an unusual and rare shade perennial that emerges in early spring with warm burgundy stems with a whorl of four mid green, textured, slightly shiny, serrated leaves each about 3-5 inches long topped with a short spike of feathery white flowers [14]. Flowers are white and flowering in March to April.

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The purpose of this paper was to describe a statistical analysis for detecting a species association, which is valid even when the assumption of within- species spatial randomness is violated. The present study used the point pattern analysis method to investigate the variation in the spatial distribution pattern of *C. japonicus* at different spatial scales and spatial autocorrelation at different plots in a 16 × 32 m^2 spatial scales at the Mountain Ahop in Korea.

Materials and Methods

Surveyed regions

This study was carried out on the populations of *C. japonicus*, located at Mt. Ahop (346.5 m) (35°16′N/129°11′E) in Busan-ci (Korea). The elevation of *community of C. japonicus* ranges from 210 to 245 m. The site is characterized by a temperate climate with a little hot and long summer. In this region the mean annual temperature is 14.7℃ with the maximum temperature being 29.4℃ in August and the minimum -0.6℃ in January. Mean annual precipitation is about 1519.1 mm with most rain falling period between June and August.

Sampling procedure

Many quadrats at Mt. Ahop were randomly chosen for each combination of site x habitat, so that, overall, 50 quadrats were sampled for the complete experiment. Spatial ecologists use artificial sampling units (so-called quadrats) to determine abundance or density of species. The number of events per unit area are counted and divided by area of each square to get a measure of the intensity of each quadrat. I randomly located quadrates in each plot which I established populations. The quadrat sizes were 2 m × 2 m, 2 m × 4 m, 4 m × 4 m, 4 m × 8 m, 8 m × 8 m, 8 m × 16 m, 16 m × 16 m, and 16 m × 32 m.

Index calculation and data analysis

Given the above definition of spatial autocorrelation, it is expected that the x - y coordinates of points (e.g. individual plants) having a spatial structure are more likely to be spatially close than expected by chance alone. Following this simple idea, the nearest neighbor method measures the mean nearest distance for all points d*i*, where *i* =1 for the first neighbor [21]. The spatial pattern of *C. japonicus* was analyzed according to the Neatest Neighbor Rule [3, 15].

Average viewing distance (r_A) was calculated as follows:

$$r_A = \sum_{i=1}^{N} r_i / N \ \ (i = 1, 2, 3 \dots N)$$

The r_i is the distance from the individual to its nearest neighbor individual. N is the total number of individuals within the quadrat.

The expectation value of mean distance of individuals within a quadrat (r_B) was calculated as follows: $r_B = 1/2\sqrt{D}$

Where D is population density and the number of individuals per plot size.

$$R = r_A / r_B$$

The significance index of the deviation of R that departs from the number of "1" is calculated from the following formula [15].

$$C_R = \frac{r_A - r_B}{\delta_{rB}}\ ,\ \delta_{rB} = 0.2613/\sqrt{ND}$$

One test for spatial pattern and associated index of dispersion that can be used on random-point-to-nearest-organism distances was suggested by Eberhardt [5] and analyzed further by Hines and Hines [11]: $I_E = (s/m)^2 + 1$

Where I_E = Eberhardt's index of dispersion for point-to-organism distances, s = observed standard deviation of distances, m = mean of point-to-organism distances. Many spatial dispersal parameters were calculated the degree of population aggregation under different sizes of plots by dispersion indices: index of clumping or the index of dispersion (*C*), aggregation index (*CI*), mean crowding (M*), patchiness index (PAI), negative binominal distribution index *K*, *Ca* indicators (*Ca* is the name of one index) [16] and Morisita index (*IM*) were calculated with Microsoft Excel 2014. The formulae are as follows:

Index of dispersion: $C = S^2 / m$

Aggregation index $CI = \frac{S^2}{m} - 1$

Mean crowding $M^* = m + \frac{S^2}{m} - 1 = m + CI = m + C - 1$ -1

Patchiness index $PAI = \frac{m}{\frac{S^2}{m} - 1} = \frac{M^*}{m}$

Aggregation intensity $PI = k = m^2/(S^2 - m) = \frac{m}{CI} = \frac{m}{C-1}$

Ca indicators $Ca = 1 / k$

$$\text{IM} = \frac{n\Sigma m(m-1)}{nm(nm-1)}$$

Where S^2 is variance and m is mean density of plants.

The mean aggregation number to find the reason for the aggregation of *C. japonicus* was calculated [1].

$$\delta = mr/2k$$

Where r is the value of chi-square when 2 k is the degree of freedom and k is the aggregation intensity. Green index (GI) is a modification of the index of cluster size that is independent of n [9].

Results and Discussion

Population densities (D) varied from 0.356 to 2.270, with a mean of 1.527(Table 1). Small quadrate sizes such as 2 m × 2 m, 2 m × 4 m, and 4 m × 4 m have relatively high D values (>2), whereas larger or wider quadrate sizes such as 8 m × 16 m, 16 m × 16 m, and 16 m × 32 m have, comparatively, very low D values (<1). The values (*R*) of spatial distance (the rate of observed distance-to-expected distance) among the nearest individuals were higher than 1 and the significant index of CR was >2.58. If by this parameter, the all plots (2 m × 2 m, 2 m × 4 m, 4 m × 4 m, 4 m × 8 m, 8 m × 8 m, 8 m × 16 m, 16 m × 16 m, and 16 m × 32 m) of *C. japonicus* at Mt. Ahop were uniformly distributed in the forest community. Thus, *C. japonicus* were not aggregately distributed in this Mt. Ahop population. The expected value of I_E in a random population is 1.27. Values below this suggest a regular pattern, and larger values indicate clumping. I_E values for all quadrates are larger than 1.27. Under the hypothesis, population of *C. japonicus* is clumping. Clumped dispersion is often due to an uneven distribution of nutrients or other resources in the environment. It can also be caused by social interactions between individuals. Additionally, in organisms that don't move, such as plants, offspring might be very close to their parents and show clumped dispersion patterns. Patchy seed dispersal near the mother plants explains the aggregation of seedlings around reproductive plants [6, 7].Within a single habitat, some areas are more ideal to live in than others because they have more food, water, sunlight, or other resources. This can cause many individuals of a population to accumulate in this ideal location.

The values dispersion index (*C*) at Mt. Ahop were lower at six plots (2 m × 2 m, 2 m × 4 m, 4 m × 4 m, 4 m × 8 m, 8 m × 8 m, and 8 m × 16 m) than 1 except two large plots (16 m × 16 m and 16 m × 32 m) (Table 2). Thus these aggregation indices (*CI*) were negative at Mt. Ahop, which indicate a uniform distribution. Two large plots (16 m × 16 m and 16 m × 32 m) were positive. However the values were not large (0.009 for 16 m × 16 m and 0.038 for 16 m × 32 m). The mean crowding (*M**) and patchiness index (*PAI*) showed positive values for all plots. When the three indices *C*, *M**, *PAI* were <1 and their values of *PI* and *Ca* were also shown smaller than zero, it means uniform distributed. In

Table 1. Spatial patterns of *Chloranthus japonicus* individuals at different sampling quadrat sizes in Mt. Ahop

Quadrat size (m × m)	Density	*R*	*CR*	I_E	Distribution pattern
2 × 2	2.750	1.780	4.950	1.507	Uniform
2 × 4	2.250	2.627	13.206	1.607	Uniform
4 × 4	2.188	2.724	19.516	1.368	Uniform
4 × 8	1.688	2.602	22.530	1.314	Uniform
8 × 8	1.359	2.522	27.172	1.710	Uniform
8 × 16	0.953	2.032	21.805	1.792	Uniform
16 × 16	0.671	1.818	18.640	1.893	Uniform
16 × 32	0.356	1.223	5.744	1.992	Uniform

Table 2. Changes in gathering strength of *Chloranthus japonicus* at different sampling quadrat sizes

Quadrat size	No.	Aggregation indices						
(m × m)	Quadrat	*C*	*CI*	*M**	*PAI*	*PI*	*Ca*	*IM*
2 × 2	16	0.433	-0.566	0.024	0.040	-1.042	-0.960	0.047
2 × 4	10	0.531	-0.469	0.407	0.465	-1.867	-0.536	0.496
4 × 4	8	0.339	-0.661	0.259	0.282	-1.392	-0.718	0.291
4 × 8	6	0.331	-0.669	0.387	0.366	-1.579	-0.634	0.371
8 × 8	5	0.768	-0.232	0.850	0.785	-4.659	-0.215	0.794
8 × 16	2	0.892	-0.108	1.018	0.904	-10.443	-0.096	0.911
16 × 16	2	1.009	0.009	1.139	1.008	122.820	0.008	1.014
16 × 32	1	1.038	0.038	1.084	1.037	27.369	0.037	1.042

C. japonicus, the two indices, *C*, *PAI* were >1 and their values of *PI* and *Ca* were also shown greater than zero, thus it means aggregately distributed. Thus, two large plots (16 m × 16 m and 16 m × 32 m) of *C. japonicus* at Mt. Ahop were clustered. The results were inconsistent with the previous results. One of the reasons is in uneven collection and distribution pattern of the *C. japonicus* was quadrat-sampling dependent. Morisita index (*IM*) is related to the patchiness index (*PAI*) and showed an overly steep slope at the plot 2 m × 4 m. The values of δ were varied from 0.018 for 16 m × 16 m to 1.284 for 4 m × 8 m (Fig. 1). The values of δ showed a tendency to decrease as the plot size increased. As Morisita's coefficient estimates spatial distribution pattern using the mean and variance of each sampling date separately, so this index is more perfect than dispersion index [17]. The detailed knowledge of dispersion in different time intervals during growing season would be useful for research strategies more than management programs. When the area was larger than 16 m × 16 m, the degree of aggregation increased significantly with increasing quadrat sizes, while the patchiness indices did not change from the plot 4 m × 4 m to 4 m × 8 m. Green index varied between -0.561 to 0.213 (Fig. 2).

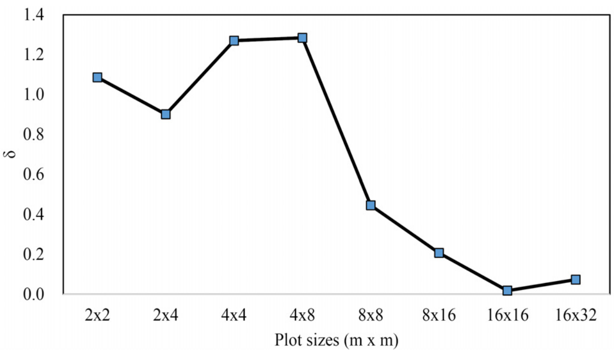

Fig. 1. The mean aggregation number to find the reason for the aggregation of *Chloranthus japonicus*.

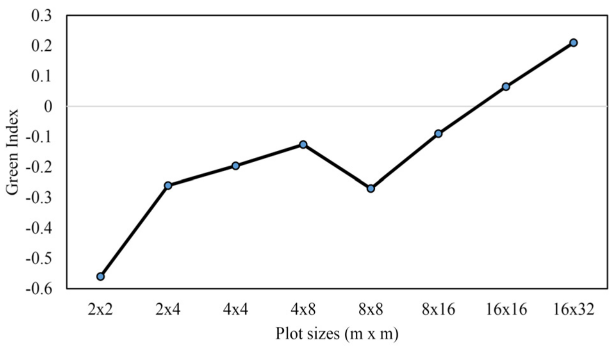

Fig. 2. The curves of patchiness in two areas of *Chloranthus japonicus* using values of Green index.

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초록 : 아홉산 홀아비꽃대 집단의 공간적 분포 양상

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지역 미세 환경의 패치는 식물의 공간적 분포에 일차적 요인이다. 식물의 공간적 양상을 결정한다는 귀무가설을 임의화 과정을 통해 검증하였다. 홀아비꽃대는 초본으로 홀아비꽃대과(Chloranthaceae) 홀아비꽃대속(Chloranthus)에 속한다. 홀아비꽃대의 공간적 양상을 여러 패치 지표로 분석하였고, 분산 지수에 따른 플롯 크기별 운집 분포, 균일분포, 공간적 상관관계를 분석하였다. 홀아비꽃대의 집단 밀도(D)는 0.356에서 2.270으로 평균은 1.527이었다. 아홉산 홀아비꽃대의 분산지표(C)는 작은 플롯(2 m × 2 m, 2 m × 4 m, 4 m × 4 m, 4 m × 8 m, 8 m × 8 m, and 8 m × 16 m)은 1보다 작았으며 큰 플롯(16 m × 16 m and 16 m × 32 m)은 1보다 상회하였다. 따라서 홀아비꽃대의 운집지표(CI)는 작은 플롯에서 음의 값으로 균일한 분포를 이룬다. 큰 플롯의 운집지표는 양의 값으로 나타났으나 그 값은 높지 않았다. 평균 클라운딩(*M**)과 패치지수(*PAI*)는 모든 플롯에서 양의 값을 보였다.