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Distribution Patterns of Species Populations along the Environmental Gradients in Mt. Moak Provincial Park, Korea

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環境傾度에 의한 母岳山 植物個體群의 分布類型

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ABSTRACT

The environmental gradient analyses were applied for the distribution patterns of species populations in Mt. Moak provincial park in Korea. The species populations were sequentially ordered along the environmental gradients such as soil moisture, soil pH, soil organic matter content and elevation and were grouped into seven ecological groups by the two-dimensional analyses of temperature-moisture gradient : *Zelkova serrata* group on mesic-lower parts near the streams and well drained stony slopes, *Carpinus tschonoskii* group on mesic-middle parts, *Quercus acutissima* group on lower parts destroyed by human activities, *Quercus variabilis* group on xeric-middle parts, *Quercus serrata* group on xeric-upper middle parts, *Quercus mongolica* group on xeric-upper parts and *Pinus densiflora* group on xeric-rock ridge lines, hillocks and lower parts interfered by human. Four forest vegetation types, zelkova forest dominated by the *Z. serrata* group on ravines and stony slopes, hornbeam forest dominated by the *C. tschonoskii* group on mesic-middle parts, oak forest dominated by the groups of *Q. acutissima*, *Q. variabilis*, *Q. serrata* and *Q. mongolica* on xeric sites and pine forest dominated by the *P. densiflora* group on dry and poor sites, were separated in mosaic chart by the two-dimensional analysis.

INTRODUCTION

Since, in general, vegetation is spatially heterogeneous and its constituent species show certain distribution patterns(Greig-Smith, 1979), the examinations on the distribution of species populations are expected to be a great help for the understanding of vegetation structure.

Environmental gradient analysis is an approach for the study of spatial patterns of vegetation and seeks to understand the structure and variation of the vegetation in terms of gradients in space of variables on three levels—environmental factors, species populations and characteristics of communities(Whittaker, 1967). The concept of environmental gradient analysis does not differ in principle from the approaches of ecological species group derivation and ecological classification. All three relate to the analysis of species and community distribution along known environmental gradient(Mueller-Dombois and Ellenberg, 1974). The environmental gradient analysis can contribute to elucidate the underlying causes of species population distribution.

According to Walter(1971), a plant community is understood to be a more or less stable combination of naturally occurring species, which are in an equilibrium with one another and their environment. It has commonly been accepted that the composition of vegetation determined by its habitat—vegetation is the best measure of environment. Therefore, the approach from environment to floristic analysis is considered to be a prerequisite for recognizing a plant grouping as a community.

In this point of view, a study on the distribution pattern of species populations along environmental gradients and on the relationships between vegetations and environments was carried out in Mt. Moak provincial park in Chôllabuk-do, Korea.

SITE DESCRIPTION

The Mt. Moak provincial park area(ca. 42.22 km^2) is located on 35° 41′ 15″ - 35° 45′ 30″ N and 127° 01′ 00″ - 127° 06′ 30″ E, about 10 km south of Chônju, Korea(Fig. 1). The upper part of the mountain(801m in altitude) is largely characterized by steep solpes or rock ridges. The soils of the mountain show stony loam and stony sandy loam on the upper parts, gravelly loam and gravelly sandy loam on the lower parts and sandy loam on flat land(Office of Rural Development, 1975).

The vegetation of this region was known as a cool-temperate forest southern zone at the formation level(Yim and Kira, 1975). Many trees and herbaceous plants in the park area had been repeatedly cut for the wood use and grazed for domestic animals, food and shifting agriculture. Since 1972 when this area was designated as the provincial park area, the plantations of pine(*Pinus rigida* and *P. koraiensis*) have been increased and now the park area is largely covered with oak(*Quercus*) forest on upper middle slopes and pine(*Pinus*) forest on lower slopes. The climatological data of Kûmsansa temple(120 m in altitude) in the mountain show 1,290 mm in mean annual precipitation, 8.3℃ in annual mean temperature with variations from −17.0℃ in January to 38.2℃ in August. Kira's moisture index 65.6(Yim and Kira, 1976) and climate diagram(Fig. 2) based on the data of Chônju meteorological station(Central Meteorological Office, 1984) were referred to the analyses of distribution patterns of species populations.

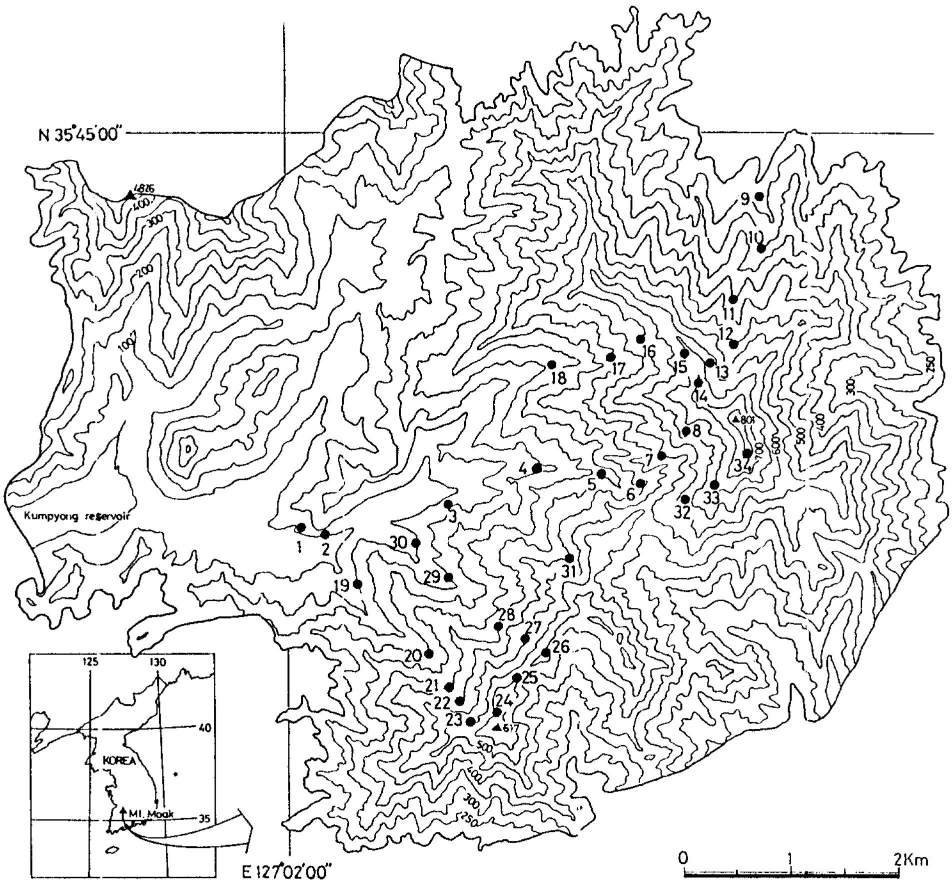


Fig. 1. Map showing the study sites(●) and the boundaries of Mt. Moak provincial park area of Chôllabuk-do, Korea.

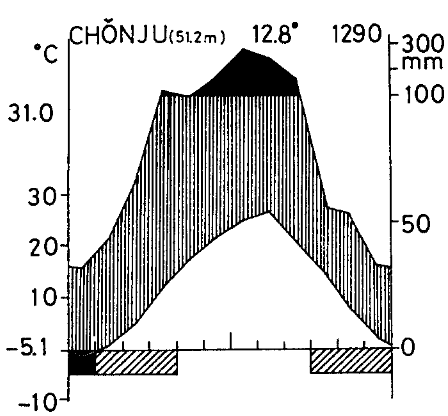


Fig. 2. Climate diagram of Chônju near Mt. Moak. The two curves show monthly mean temperature(℃) and precipitation(mm) : barring where the precipitation curve lies above the temperature curve presumably represents humid season, black area(mean monthly precipitation in excess of 100 mm), perhumid season, and black box, indicating month with a mean daily minimum below 0℃, cold season. Additional information in the figure includes elevation, 51.2 m, annual mean temperature, 12.8℃, mean annual precipitaion, 1,290 mm, mean daily temperature maximum of the warmest moth, 31.0℃ and mean daily temperature minimum of the coldest month, −5.1℃.

MATERIALS AND METHODS

Vegetation survey

Quadrats of 10m×10m or 15m×15m in minimal area were set randomly at thirty four sites, 1985~1988(Fig. 1). The floristic composition, tree census and habitat conditions were described. Soil samples of B horizon in each quadrat were air-dried and sifted through 20-mesh sieve for chemical analyses and 60-mesh for organic matter measurement(Kim *et al.*, 1986). Soil pH was determined in soil solution(soil : distilled water=1:5, w/v) by glass electrode. Soil moisture content was calculated as loss water percentage against dry soil weight at 105℃. Soil organic matter content was determined as a percentage of the loss-on-ignition in 800℃ against dry soil weight(Kim and Yim, 1986, 1988; Kim *et al.*, 1988).

Gradient analysis

Soil moisture, pH and organic matter content for soil condition and elevation(temperature) for climatic condition were selected, and these factors were standardized in a scale of 1 to 10, respectively. Importance values for dominant trees calculated as the sum of relative density, relative coverage and relative frequency(Curtis and McIntosh, 1951) were plotted along the gradient of soil moisture, soil pH, soil organic matter content or elevation, rank 1 to 10.

Pattern analysis

For the distribution pattern analyses of species populations, two complex gradients of elevation and topographical moisture gradient were used as the axes of two-dimensional charts. The importance values of dominant species populations were plotted on the two-dimensional charts. A mesic to xeric change in topographical moisture gradient was determined with soil moisture content referred to as topographic categories such as sheltered slopes and open slopes or coves and ridges, etc. The isoplethes of importance values were used for the distribution centers of dominant species populations. To elevate the distribution pattern of species populations, the mosaic chart, i.e. a synthesis chart of the species population charts, was constructed using ordination-based pattern analysis by Whittaker(1956, 1967, 1975; Shmida and Whittaker, 1981).

RESULTS

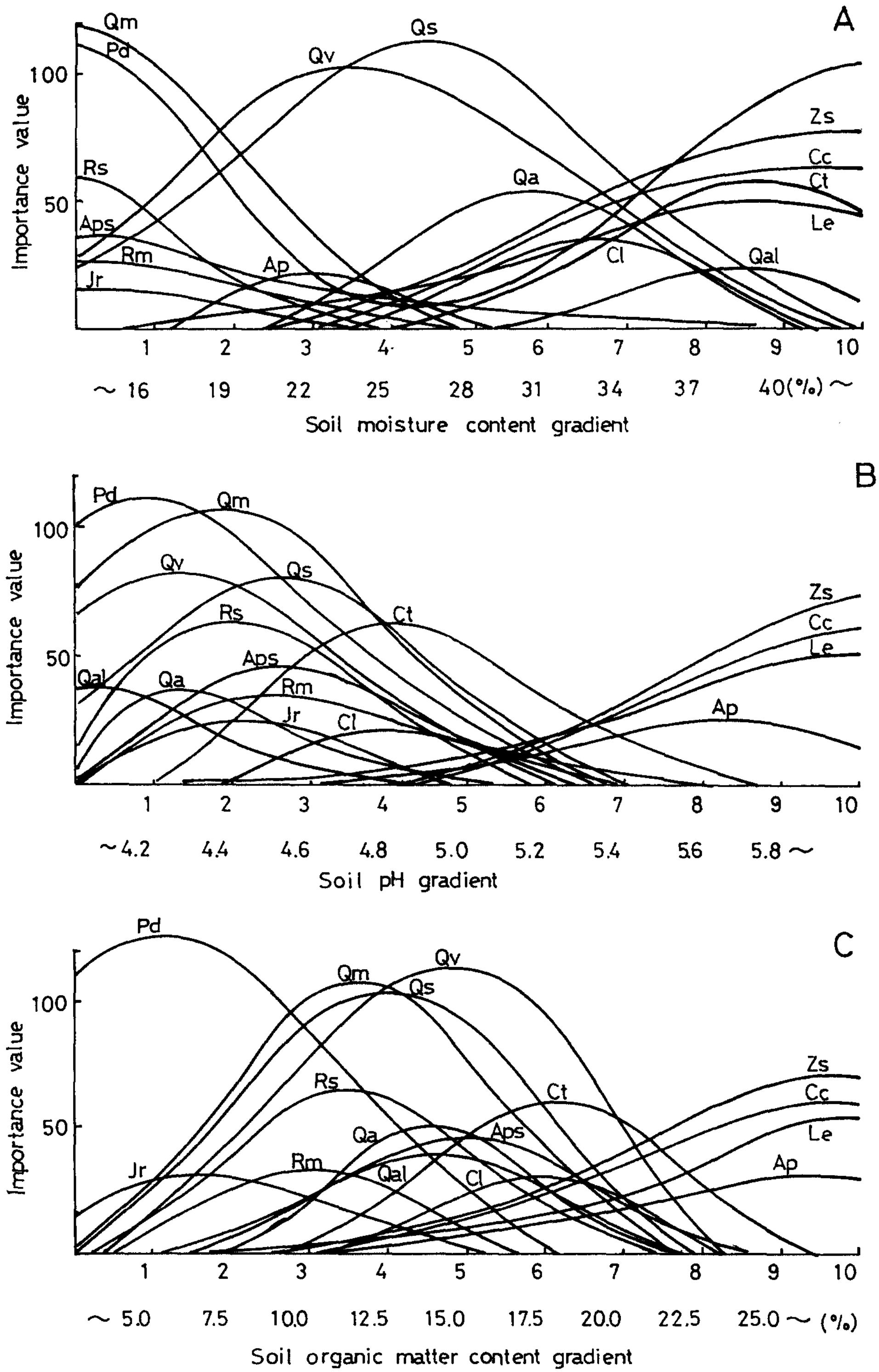
Distribution of species populations along environmental gradients

The distributions of different species populations along environmental gradients of soil moisture, soil pH, soil organic matter content and elevation showed typical bell-shaped curves with single peaks. The peaks of different species populations in the soil moisture gradient from mesic to xeric sites showed the sequence of *Zelkova serrata*, *Cornus controversa*, *Lindera erythrocarpa*, *Carpinus tschonoskii*, *Quercus aliena*, *Carpinus laxiflora*, *Quercus acutissima*, *Quercus serrata*, *Quercus variabilis*, *Acer palmatum*, *Acer pseudo-sieboldianum*, *Quercus mongolica* and *Rhododendron schlippenbachii*, *Juniperus rigida*, *Pinus densiflora* and *Rhododendron mucronulatum*(Fig. 3-A). Based on the behaviors of the tree and shrub species populations, they could be divided into several ecological groups(Ellenberg, 1956) as in Mt. Seonun and Mt. Naejang(Kim and Yim, 1986, 1988).

In the soil pH gradient from acid to alkali, the peaks of different species populations showed the sequence of *Z. serrata*, *C. controversa*, *L. erythrocarpa*, *A. palmatum*, *C. tschonoskii*, *C. laxiflora*, *Q. serrata*, *R. mucronulatum*, *J. rigida*, *A. pseudo-sieboldianum*, *R. schlippenbachii*, and *Q. mongolica*, *Q. acutissima*, *Q. variabilis*, *Q. aliena* and *P. densiflora*(Fig. 3-B). Under highly acidic conditions, most phosphate is bound in forms unavailable to plants, nitrogen fixing and nitrifying bacteria are strongly inhibited and exchangeable cations are largely displaced from exchange sites by hydrogen and aluminum ions and hence are easily leached(Black, 1968). On the other hand, some micronutrients such as iron and manganese increase in availability and can reach toxic levels. Aluminum also tends to increase in acid soils and become toxic(Goldberg, 1982). For these acid soils, soil pH can be considered as a monotonic index of relative nutrient availability. The effect of soil pH on the distribution of species population, however, does not seem to be clear in this mountain.

The sequence of the peaks of different species populations in soil organic matter content gradient, from fertile to infertile, was *Z. serrata*, *L. erythrocarpa*, *C. controversa*, *A. palmatum*, *C. tschonoskii*, *C. laxiflora*, *A. pseudo-sieboldianum*, *Q. aliena*, *Q. acutissima*, *Q. variabilis*, *Q. serrata*, *Q. mongolica*, *R. schlippenbachii*, *R. mucronulatum*, *J. rigida* and *P. densiflora*(Fig. 3-C). Since 1972 when lumbering and grazing for timber and fuel was abandoned in the mountain, the forest floor have been covered with fallen leaves every year and soils of the undergrowth become more fertile, more mesic and weaker in acidity gradually, and hence the distributions of species populations at present can be expected to be altered.

The peaks of different species populations from low to high elevation showed the sequence of *Q. aliena*, *P. densiflora*, *R. mucronulatum*, *J. rigida*, *Q. acutissima*, *A. palmatum*, *C. tschonoskii*, *L. erythrocarpa*, *C. controversa*, *Z. serrata*, *C. laxiflora*, *Q. variabilis*, *Q. serrata*, *R. schlippenbachii*, *A. pseudo-sieboldianum* and *Q. mongolica*(Fig. 3-D). Mongolian oak(*Q. mongolica*) among the deciduous species is largely frost-tolerant and increases in abundance as elevation increases in the mountain. Therefore, the elevation gradient can be regarded as a natural experiment wherein an increasing elevation increases the population density of monglian oak. Based on the behaviors of tree and shrub species populations in the same peak class, they could also be divided into several ecological groups as in moisture gradient analysis.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Soil moisture content gradient
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Soil organic matter content gradient

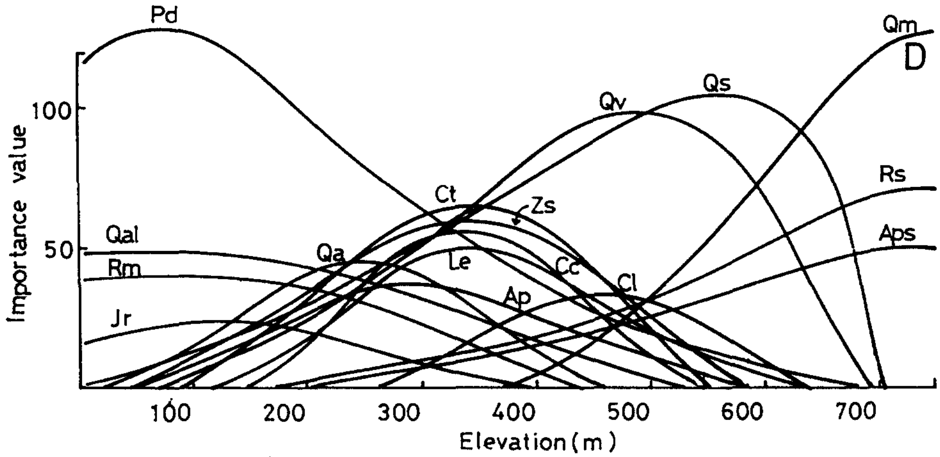

Fig. 3. Species population curves along environmental gradients of soil moisture content(A), soil pH (B), soil organic matter content(C) and elevation(D) in Mt. Moak. Curves were plotted with importance values of trees : Ap; *Acer palmatum*, Aps; *Acer pseudo-sieboldianum*, Cc; *Cornus controversa*, Cl; *Carpinus laxiflora*, Ct; *Carpinus tschonoskii*, Jr; *Juniperus rigida*, Le; *Lindera erythrocarpa*, Pd; *Pinus densiflora*, Qa; *Quercus acutissima*, Qal; *Quercus aliena*, Qm; *Quercus mongolica*; Qs; *Quercus serrata*, Qv; *Quercus variabilis*, Rm; *Rhodoendron mucronulatum*, Rs; *Rhododendron schlippenbachii*, Zs; *Zelkova serrata*.

The effects of soil moisture and elevation gradients on the distribution of species populations were the most evident among the environmental factors examined.

Distribution pattern of species populations

The results of two-dimensional analyses with temperature(elevation) and moisture(or topographic) gradient showed that species are distributed continuously according to the Gleason's principle of species individuality(Whittaker, 1951, 1956, 1967) and are arbitrarily grouped into seven sets of species or ecological groups, having the same or close population distribution centers(upper side of the Fig. 4). *Z. serrata* was grouped into a set with *C. controversa* and *L. erythrocarpa* having the same or close distribution center, *C. tschonoskii* with *C. laxiflora*, *Q. mongolica* with *R. schlippenbachii* and *A. pseudo-sieboldianum*, *P. densiflora* with *R. mucronulatum* and *J. rigida* etc. The distribution centers of the seven sets of species populations were found in characteristic sites one another(lower side of Fig. 4) as follows : *Z. serrata* group on mesic-lower parts near the mountain streams and well drained stony slopes, *C. tschonoskii* group on mesic-lower middle parts of the slope in the mountain, *Q. acutissima* group on lower parts of the slope destroyed by human activities, *Q. variabilis* group on xeric-middle parts of the slope, *Q. serrata* group on xeric-upper middle parts parts of the slope, *Q. mongolica* group on xeric-upper parts of the slope and *P. densiflora* group on xeric-rock ridge lines and hillocks, dry and poor habitats, and on lower parts destroyed by human interferences.

The forest vegetation pattern of Mt. Moak showed four types in mosaic chart of the

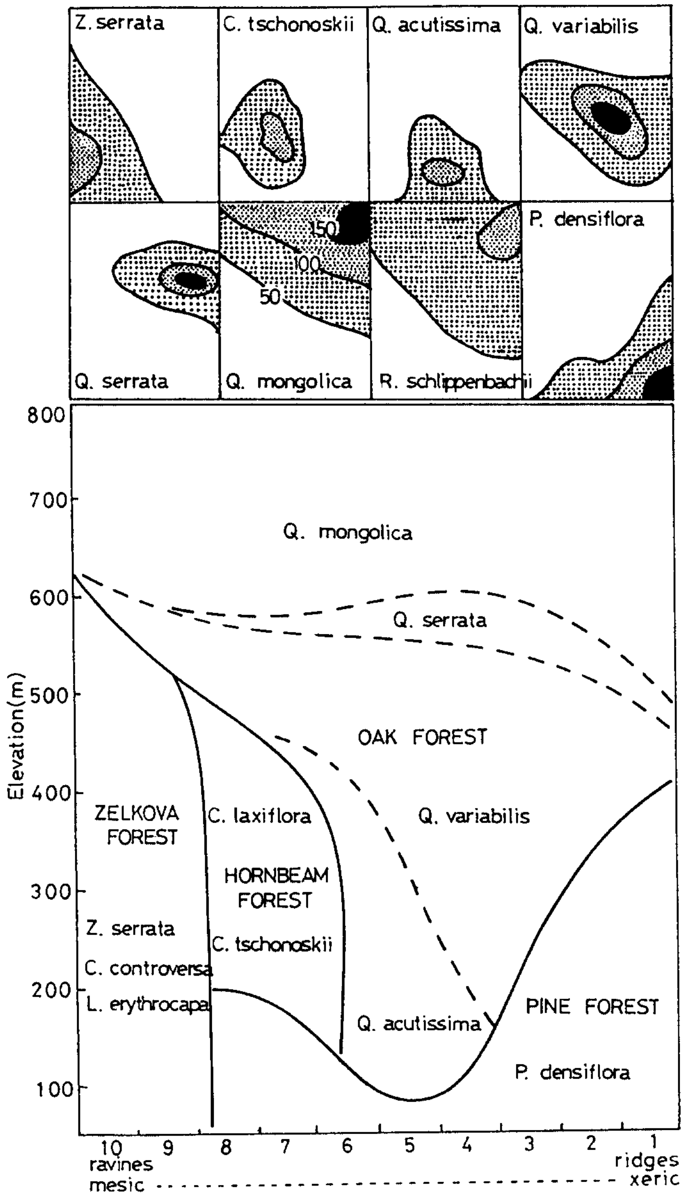

Fig. 4. Species population charts for the distribution centers of eight dominant species(upper side) and mosaic chart for the distribution patterns of seven ecological groups and for the forest vegetation pattern of Mt. Moak(lower side). Arabic numerals on the lines stand for the isopleth of importance values of each species population. For the chart the vertical axis indicates the gradient of temperature and other factors related to elevation and the horizontal axis indicates the gradient of moisture and other factors related to moisture from mesic to xeric sites.

groups : zelkova forest dominated by the *Z. serrata* group on ravines and stony slopes, hornbeam forest dominated by the *C. tschonoskii* group on moist-middle parts, oak forest dominated by the groups of *Q. acutissima*, *Q. variabilis*, *Q. serrata* and *Q. mongolica* on xeric sites of different elevations, and pine forest dominated by the *P. densiflora* group on dry and poor sites(lower side of the Fig. 4).

As mentioned above, species populations of the mountain were divided into seven ecological groups by environmental gradient analyses and two-dimensional analyses of temperature-moisture gradient and four forest vegetation patterns were derived from the seven groups.

DISCUSSION

Direct gradient analysis by Whittaker(1951) assumes that vegetation properties are related to mesoscale climate(elevation) and topography(moisture index) as the axes of the gradient analysis diagrams when parent material, biotic factor and time are constant (Austin *et al.*, 1984). Thus direct gradient analysis by Whittaker can be said to be a graphical analysis procedure for a one or two-factor to the study of vegetation. The idea of analyzing vegetation and species pattern graphically in relation to explicit environmental gradients is essentially simple but does have weakness that the graphic illumination of complex ecological problems makes the minor difficulties of interpretation acceptable. To detect the complex distribution patterns of individual species and vegetation, however, functional factorial approaches incorporated the factors of patent material, resource and time as variables have been appeared(Greig-Smith, 1979; Dyrness and Grigel, 1979; Whittaker *et al.*, 1983; Austin *et al.*, 1984).

Environmental gradients can be described by the concept of three types–indirect, direct and resource gradient(Austin *et al.*, 1984). Indirect or complex environmental gradients, e. g. elevation, are those whose influence on plant growth is indirect. Direct environmental gradients, e. g. pH, are those where the factor has a direct physiological effect on plant growth, while resouce gradients, e. g. nitrogen, are those where the factor is directly used as a resource for plant growth. In order to understand vegetation–environment relationships we need to analyze the vegetation by the three types for expressing environmental gradients of variables.

Elevation is an indirect environmental complex gradient related with rainfall, wind and temperature which are responsible for changes in vegetation performance. These variables also change in a complex fashion with latitude and longitude. No simple physical process model can estimate them at present but statistical procedures exist which can provide a prediction for either temperature or rainfall, given the elevation, latitude and longitude of a sites. The use of topographic measure is an another one related with moisture and light intensity which are important for plant distribution. Soil moisture content and soil pH as direct environmental gradient and soil organic matter content as resource gradient were used as an axis of simple factor gradients in Whittaker's term, respectively, in distribution

pattern analysis of species populations.

In one-dimensional gradient analyses based on the single factor gradients the species populations showing the bell-shaped curves with single peak in different classes were sequentially ordered along the gradients, respectively in all cases as in Mt. Seonun and Mt. Naejang(Kim and Yim, 1986, 1988). In distribution pattern analysis of ecological species groups based on two-dimensional analysis of elevation and topography used as axes of complex gradients, seven ecological species groups could be discriminated in the mosaic chart for the distribution pattern of species population types. Consquently, soil moisture content, soil pH and soil organic matter content as direct environmental factor and elevation and topography as complex one seem to have strong influence on the vegetation but the transition zones between seven ecological species groups each other may be wide. The groups, however, are independent functionally of each others although vegetation change is gradual along the gradient.

In conclusion, pattern analyses have effectively demonstrated relationships between spatial patterns of vegetation and environments in this mountain. Therefore, the pattern analysis approach can be useful as a heuristic method for the detection of relationships between vegetations and environments.

摘 要

母岳山 道立公園 植物個體群의 分布類型을 環境傾度에 의해서 分析하였다. 土壤濕度, pH, 土壤有機物合量 및 高度(溫度)의 傾度에 따라 植物 個體群들이 順序的으로 配列되었으며 溫度-濕度의 二次元 分析에 의한 그들 分布 中心의 類似度를 考慮하여 溪谷과 轉石地 附近에 分布하는 느티나무 群落, 濕한 中 斜面의 개서어나무 群落, 高度 300 m 以下 斜面 下部의 상수리나무 群落, 乾燥한 斜面 中部의 굴참나무 群落, 斜面 中上部의 졸참나무 群落, 斜面 上部의 신갈나무 群落과 岩石地帶, 산등성이 또는 人間의 干涉이 심했던 斜面 下部의 소나무 群落等 7個의 生態群으로 묶을수 있었다. 또 이들을 土臺로 同 公園의 森林植生은 느티나무, 층층나무와 비목나무가 優占하는 溪谷의 느티나무林, 개서어나무와 서어나무가 優占하는 濕한 斜面의 서어나무林, 상수리나무, 굴참나무, 졸참나무와 신갈나무가 優占하는 乾燥한 斜面의 참나무林 그리고 소나무, 리기다소나무와 잣나무가 優占하는 소나무林 等 4個의 植生型으로 類別되었다.

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