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An Application of Analysis of Concentration for Ecological Study of Foliose Lichens

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葉狀地衣植物의 生態學的 硏究에 對한 集中度分析法의 適用

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ABSTRACT

Lichen communities at the Duckyoo National Park were studied by the analysis of concentration. Thirty three species of lichen identified were divided into three vegetational groups and fourty two stands into three environmental groups by sum of square algorithm. The sharpness of the nine blocks table is low, that is C=0.05, which means the divergency of lichen communities to be high. The result reveals that canonical first variate is 0.313 (91%) and second variate 0.100 (9%), and calculates the expected deviation from the first variate. The intermediate zone of environmental group is more important area to distribute lichen species than other zone.

The computer program for this study was made by APPLE SOFT BASIC (DOS 3.3).

INTRODUCTION

Analysis of concentration (AOC) is one of the canonical methods which are powerful in analyzing and describing the complex multidimensional data (Feoli and Orloci, 1979). In plant ecology, the interpretation of the interaction among species within vegetation and various environmental factors has been used by means of the powerful techniques such as multiregression, principal component analysis (PCA), canonical analysis (CA) and discriminant analysis (DA) (Williams, 1971; Sneath and Sokal, 1973; Orloci, 1978; Greig-Smith, 1983; Legendre and Legendre, 1983).

Those techniques are useful to reduce the number of dimensions of variable factors and to extract trend of the variables affecting the factors of vegetations. Although multivariate statistical methods such as the PCA, CA and DA are available to reduce dimensions in vegetational structure and to interpret the trend of data of vegetation and environment, these methods can not examine in detail variation of the identified components.

The analysis of concentration technique derives canonical analysis, as do other two methods such as canonical correlation and canonical variate analysis. Vegetational and environmental structures could be arranged in blocks containing non-zero values (Feoli and Orloci, 1979). The non-zero blocks are called as "concentrated". The concentrated blocks can be divided into the vegetational and environmental data, and then can be interpreted interrelations among them.

The studies of distribution of lichen communities were carried out in Canada by See and Bliss (1980) and Nimis (1981) and in America by Johnson (1981), Rushforth et al (1982) and McCune and Antos (1982). All of them were descriptive the patterns of distribution of lichen communities but in recent years the study of distribution of lichen communities using multivariate statistical methods has been superseded by techniques collectively called ordination, cluster analysis and analysis of concentration.

This study attempts to present the process and results of the AOC technique with a set of data on lichen community. The emphasis is focused on the three issues; the test of sharpness of the block tables which means the reliability among them, eigenanalysis of data sets which classified between vegetation and environment components and deviation expected of lichen distribution for the environment.

STUDY AREA

Data on foliose lichens were collected from 42 stands at three mountains within the Duckyoo National Park (35°82′N;128°73′E), Korea. Of 42 stands, 21 stands were from Mt. Duckyoo, 12 from Mt. Jeocksang and 9 from Mt. Namduckyoo. All sampling stands are lain at higher than 800m in elevation. The climate of the sample stands is influenced by air masses moving in land from the South China Sea. The mean annual precipitation at low altitudes of the Park is about 1300mm. The bulk of rainfall concentrates for the summer, but winter is relatively dry. The mean temperatures for January and July are −2°C and 27°C, respectively.

The sample stands are lain under a predominant secondary forest consisting of Taxaceae, Pinaceae, Berberidaceae, Rhodoraceae and Alangiaceae. Lichens are typically developed well in all sample stands, especially these predominate in moist stands. The most abundant lichens in the study area are generally species of *Bryoria*, *Cladonia*, *Anzia*, *Lobaria* and *Parmelia*.

METHODS

A) Sampling

Each sample stands were laid out 400m² in area. Within each quadrat, ten 10 cm × 20 cm adjacent quadrats were set. These adjacent quadrats were made on a bark of from 3 to 7 trees in each of stands (Park, 1983).

Cover of lichens as estimated by Daubenmier's method (1959) modified in cover classes. Exposure side and canopy density were also estimated (McCune, 1982).

Common species of lichens were identified by morphological and anatomical characters (Hale, 1979). However, species which were difficult in identification, such as *Paarmelia*, *Cladonia* and *Physcia*,, intensively analyzed their lichen products by thin layer chromatography (Culberson, 1972).

B) Data Analysis

1. Sharpness

The nature of the block table in terms of "sharpness(C)" is homogeneity upon which the vegetational and environmetal blocks are classified by sum of square algorithm (SSA). The sharpness of block table is assessed by use of chi-square values (χ^2), which can be shown as

$$C=\chi^2/F_{..} \min\ (p-1, q-1) \cdots\cdots (1)$$

Where p and q are species groups and quadrat groups in Table 1 and $F_{..}$ is grand total of frequencies (529 in Table 2). The sharpness value ranges from o to unity, zero indicates the maximum divergence and unity the perfectly homogeneous condition in plant community.

The block table is adjusted by PROGRAM ADJUST (Orloci, 1984).

2. Canonical Analysis

Canonical analysis is used to interpret biological meaning by means of linear regression for two matrices which are composed of data set such as both species × vegetational variables and species × environmental variables (Williams and Lance, 1968; Noy-Meir, 1970; Gauch, 1977).

The statistical theory of the block table is developed by Williams(1952) and two sets of internal variables derived from the table are known as canonical variates and canonical correlation (Lancaster, 1969; Waloff, 1966).

The AOC technique is based on a theory developed by Lancaster (1949) and adopted by Williams (1952) and Feoli and Orloci (1979). The AOC technique incorporates a device both for testing the internal trend of vegetational variables and for decomposing external trends of environmental variables in the block tables, which corresponds to linear relationships among them.

To calculate canonical correlations, it has assumed that total chi-square (χ^2) is to equal as follows:

$$\chi^2=F_{..}R_1^2+\cdots\cdots+F_{..}R_n^2 \cdots\cdots (2)$$

where $R_1{}^2$ and $R_n{}^2$ represent canonical correlation coefficient. The eigenvalues of canonical correlation was calculated by the cross product matrix (S) among the element ($\boldsymbol{u}$),

$$S=\boldsymbol{u}'\ \boldsymbol{u} \qquad (3)$$

with elements defined by

$$U_{hj}=\frac{F_{hj}}{(F_{h.}F_{.j})^{1/2}}-\frac{(F_{h.}F_{.j})^{1/2}}{F_{..}},\quad h=1,\cdots\cdots,p;\ j=1,\cdots\cdots,q \cdots\cdots (4)$$

where $F_{h.}$ indicates the sum of rows and $F_{.j}$ the sum of columns in the table, and F_{hj} means occupied frequencies.

The associated eigenvectors are given as α_1, α_2, ……, α_n and canonical scores of vegetational group on i th canonical variate (X) are calculated as follows:

$$X_{hj} = \frac{\alpha_{hi} - \bar{\alpha}_i}{\Sigma(\alpha_{hi} - \bar{\alpha}_i)^{1/2}} \left[\frac{F_{..}}{F_{.h}}\right]^{1/2} \quad \cdots\cdots (5)$$

where α_{hi} means eigenvector and $\bar{\alpha}_i$ indicates the mean of eigenvector i th canonical variate. Canonical scores of environmental group on i the canonical variate (Y) are calculated as follows:

$$Y_{ji} = \Sigma F_{ih} X_{hi} / R_i F_j. \quad \cdots\cdots (6)$$

3. Expected deviation

Expected deviation is estimated on the basis of components being partitioned according to the trends. The partitioning element involves deviations from the lattice (X, Y) of component in $p \times q$ group. F_{jh} indicates expected deviation of the frequencies in which are important the canonical variate.

$$F_{ji(i)} - F^0_{hj(i)} = U_{hj(i)} [F_{hi} F_{.j}]^{1/2}, h=1, 2, \cdots\cdots p;\ j=1, 2, \cdots\cdots, q \cdots\cdots (7)$$

4. Computer Program

The computer programs for this study were ADJUST/PL, CONCENTRATION/PL and LATTICE/PL, and calculation was made by APPLE SOFT BASIC (DOS 3.3).

RESULTS

1. Block Table of Lichens.

The lichen block table is to be made of two underlying dimensions of species and sample stands. Thirty three species of lichen identified were grouped into three vegetational (species) groups and 42 stands into three groupings of environmental (quadrat) groups (Table 1).

From this a nine-block table was constructed by the clustering of sum of square algorithm. The raw data in Table 1 are adjusted, and then the results are transfered to Table 2.

The chi-square value calculated in between the frequencies of block and those of expected block in Table 1 is $\chi^2=57.138$. The sharpness of the table is low, that is $C \fallingdotseq .05$, which means that the divergency of the lichen community is high.

2. Analysis of Concentration

The AOC derived two independent linear components, canonical variates. The AOC was calculated from the independent linear components between the vegetational groups and the environmental groups. The canonical variate I is 0.313 (91%) and canonical variate II is 0.100(9%) which indicated the first variate is extremely important.

The canonical scores of the vegetational groups and the environmental groups are given in Table 3. The relationships among the vegetational group and the environmental variables, especially elevation, exposure side and canopy density, are summarized in Table 4.

Table 1. The lichen species and stands are arranged according to the sum of square. Numbers indicate cover of lichen by Daubenmire scale.

Species groups	Stands groups		
	1	2	3
a. *Menegazzia terebrata*	------	22------44-	111---555------111-------
Anzia ornata	------	------33---	--------222555---333-----
Dematocarpon miniatum	------	--44-------	222333------222--111-----
Anaptychia hypoleuca	--3---	---------33	1----333-----222---------
Parmelia caperata	------	--------44-	1333-333-----------------
b. *Nephroma resupinatum*	---44-	-----55----	13--222-----444----------
Parmelia marmariza	---55-	-----11----	-33333-------111333-11134
Sticta gracilis	-44---	-----------	-33333-------333---333-34
Leptogium tremelloides	------	--------22-	3-3--44----111-111-----34
Anaptychia microghylla	------	-----3311--	3-22244----22222---------
Parmelia austrosinensis	----33	------33244	3555-44-22211122------444-
Parmelia reticulata	------	--------2--	-222333----22222--222--1-
Anzia colpota	22----	------3311-	-------------111555-4441-
c. *Peltigera dolichorrhiza*	--4445	555333-----	--333---444------4443331-
Parmelia squarrosa	222--5	222--------	111----222111----111--111
Collema glaucopthalmum	--1115	-----------	--555--222-----------555-
Parmelia tinctorum	------	-----------	333222222---555-111------
Umbilicaria esculenta	222333	-444-----44	41555------------444-----
Hypogymnia physodes	---222	-555----444	---444-----------222-----
Parmelia rudecta	-555-2	22555--555-	-------------333---------
Physcia albicans	----33	3333-------	---------555111-----111555
Collema flagrans	---3--	------222--	-555222-222111---444-----
Lobaria meridionalis	1113-3	33---------	---------------333-------
Parmelia cochleata	----3--	--555----22	2-------333111-----11----
Parmelia sulphurata	--4443	33---------	-111-555-----------------
Parmelia fertilis	---555	--333------	--333----111-------------
Anaptychia palmulata	--2223	333--------	-----555-111---------222-
Anzia japonica	-----3	-5333-----4	-------333----444---333--
Parmelia subramigera	-----3	-5225553334	---444444-------------111
Lobaria orientalis	333---	-522------4	-------4443333333333------
Nephroma resupinatum	-1----	--22111-3--	------444--4-3333---------
Parmelia mexicana	-1555-	-222444-3--	--111111--4----31111-----
Leptogium tremelloides	-1-111	-111-4443--	222--------4222-3333222---

3. Expected Deviation

The interaction among the vegetational groups and the environmental groups were shown in Fig. 1. Expected deviation were calculated in the important canonical variate, which

Table 2. Joint frequecies among three vegetational groups(a, b, c) and three environmental groups (1, 2, 3) in Table 1. The entries in the cell are counts of non-zero value in the corresponding block table adjusted to minimum block size.

Vegetational groups	Environmental groups			Total
	1	2	3	
a	6.232328	40.7934196	65.8133837	112.839131
b	38.95205	42.4931454	95.3546183	176.799814
c	91.9268379	75.6377988	71.7964186	239.361055
Total	137.111216	158.924364	232.964421	529.000000

Table 3. Canonical scores and correlations for the vegetational and environmental groups in Table 1.

Canonical variate	Vegetational groups			Environmental groups			Canonical correlation
	a	b	c	1	2	3	
I	−1.4396	−.4779	1.0316	1.5569	−.0201	−.9084	.3130
II	−1.2710	1.3280	−.3817	.6346	−.5258	.6673	.1001

Table 4. Characterization of lichen communities at Mt. Duckyoo.

Level	Height	Exposure side	Canopy density	Score	
				I	II
1	(>1,000m)	South	Low	1.5569	.6346
2	(1,000~1,500)	East-West	High	−.0201	−.5258
3	(<1,500)	North	Intermediate	−.9084	.6673

is first value (0.313) indicated in 91% of significance in this study.

Deviation of environmental group and vegetational group indicates the linear form for low zone in less 1,000 m, intermediate zone from 1,000 m to 1,500 m and high zone in above 1,500 m of elevation. Both a and b group of vegetational group represented the same trend and c group inversed against a and b group.

The intermediate zone of environmental group is more important areas distributing lichen species than other zone. The moisture condition of this zone is more higher than others (Fig. 1). Expected deviation of this zone is more adjusted.

DISCUSSION

It is more difficult to predict the layout of a cryptogam plant community than a vascular plant community. Recently a number of studies reveal ordinations and cluster results which

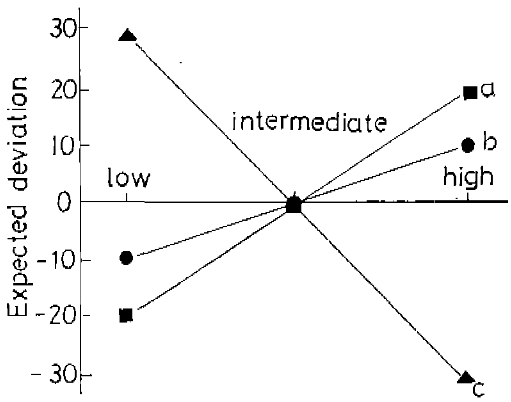

Fig. 1. Expected deviation of three vegetational groups (a, b and c). The group a and b reveal the similar gradient but group c is to show the different gradient.

were performed by Hoffman and Boe (1977), McCune and Antos (1982), Sheard and Jonescu (1975) and Park (1983). The result in this study applied the AOC technique on the distribution of lichen communities in the Duckyoo National Park.

The sharpness of the table appears very low, C value is 0.05. This value reveals divergency in the interpretation of the compositional patterns of distribution of lichen species in the Duckyoo National Park.

Canonical variate reveals two value, the first values involves 91% and the second 9% variate and the first canonical correlation is 0.313 and the second 0.100. The canonical variates appear that the first variate is more important than the second. The concept of variate analysis used to a component role in interpretation of structural pattern of environmental and vegetational group and that of canonical correlation accounted for the relationship among groups (Table 3).

The expected deviation from the first variate shows that the relationship between vegetational and environmental group indicates appropriate situation in the intermediate zone (1,000~1,500m) and the lichen distribution of this higher than other zone.

The principal concept of canonical analysis means the multiregression index between two matrices data such as complex gradient (Whittaker, 1967) and environmental scalars (Loucks, 1962). The application of analysis concentration for ecological study of lichen communities is very few now.

Feoli and Orloci (1979) introduced the AOC technique to that for grobal trends but the theoretical justification for using this technique in the distribution of lichen species is unchallenged. This technique is powerful method to separate components affecting environmental and vegetational factors than that based on the theories of Williams and Lance (1968) and Noy-Meir and Austin (1970) who defined the relationship between vegetation and environment with a small number of components.

There are at least three processes of the text of sharpness of the block tables. The extraction of component affecting vegetations, and environment factor and expected deviation of distribution of lichens in communities applied the AOC technique.

摘 要

집중도분석법(AOC)으로 덕유산 국립공원 일대의 지의식물 군락과 그 환경요인과의 관계를 분석하

였다. 42개 지소와 지의식물 33종에 대하여 거리자승파법(SSA)으로 식물과 지소의 3×3=9 분할표를 만들어 선명도(Sharpness)를 계산하고, 정준분석법(Canonical analysis)을 이용하여 분석하고 기대분산을 계산하였다.

덕유산 지의식물의 선명도는 C=0.05로 낮게 나타났다. 식물집락과 환경집락간의 정준변량은 제 1 변량이 91%, 제 2 변량이 9%로 나타났다. 정준상관치는 0.313과 0.100이었고 이는 지의식물의 분포가 보다 퍼져 있는 상태이며 지의식물과 환경과의 상관은 상당히 높은 관계를 나타냈다. 이에 대한 기대분산은 식물집락 a와 b는 c와 다른 분산을 나타냈고 지소집락은 높이 1,000~1,500m에서 기대분산에 일치함을 보였다.

모든 계산은 APPLE SOFT BASIC을 이용하여 ADJUST/PL, CONCENTRATION/PL, LATTICE/PL의 프로그램을 이용하였다.

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