MULTIVARIATE ANALYSIS OF DISTRIBUTION OF FOUR UNDERSTORY SPECIES ALONG A GRADIENT IN LODGEPOLE PINE SPRUCE FIR FOREST

Charles D. Bonham , Javed Ahmed and Larry L. Larson

Abstract

Vegetation sampling was conducted in lodgepole pine and spruce-fir forests. Fifty stands were sampled to obtain quantitative measurements of vascular plant species and the physical attributes of the site. Data analyses included principal component, McNaughton and Wolf's niche index, and discriminant and canonical anlyses. The analyses techniques identified understory sensitivity to aspect, elevation, and soil profile attributes that influence soil moisture. The understory species studied exhibited a relative independence to overstory composition and dominance.

Introduction

Multivariate analysis is useful in synecological studies as a statistical tool for dissection, discrimination, and classification. Dissection is defined as subdivision of a single population into strata given samples from the single population and numerical values for *p* variables (Kendall 1966). Given *n* populations, discrimination involves the assignment of a new sample to the correct population on the basis of data for *p* variables. Classification is used to place members of a heterogeneous population into homogeneous groups. In this study, principal components analysis (PCA) has been used for dissection, while discriminant analysis (DA) and canonical analysis (CA) have been applied to study the variability of four understory species along a gradient in lodgepole pine and spruce-fir forests.

Review of Literature

Multivariate statistical analysis techniques like PCA, DA, and CA are very powerful tools in soil and vegetation classification studies. However, their use was restricted for several decades because of limited access to computers. Now that personal computers (PC) are common, and statistical packages are available for use on PCs, more and more scientists would be able to benefit from these techniques. Some previous work that used these to economize the number of variables where some reduncancy of data is assumed. PCA is most useful when samples originate from either widely separated geographical areas or a strongly divergent environment within geographically restricted areas. Newham (1968) applied PCA to obtain a reduced list of important climatic variables from the 14 original variables. Important variables were then used in grouping 70 British Columbia weather stations into climatic regions for subsequent analysis in tree distribution studies. Barkham and Norris (1970) used PCA to

Range Science Department, Colorado State University, Fort Collins, Colorado 80523 USA

investigate major sources of variation in vegetation and soil that represented two beechwood forests of England. Walker and Wehrahn (1971) evaluated 34 marshland stands in Saskatchewan to determine the environmental influence of species distribution.

Goodall (1953) considered discriminant functions as more efficient than species indicator value for placing questionable vegetation samples into one of several communities. White and Mead (1971) used discriminant analysis of foliage nutrient levels to distinguish between two groups of slashpine. Horton *et al.* (1968) used canonical analysis to evaluate microtographic influence on soil properties. A combination of quantitative methods was used by Grigal and Goldstein (1971) to establish and refine forest type groups within a watershed in eastern Tennessee, U.S.A.

Potts and Reid (1985) used canonical analysis ot examine the major directions of population differentiation in the *Euclyptus gunnii-archeri* complex. Variation along main canonical variates was related to facets of environmental variation. Potts and Reid (1985) used PCA for analysis of a hybrid swarm between *Euclyptus risdonii* Hook. f. and *E. amygdalina* Labill. The analysis was based on morphometric characters. The variation along PCI was illustrated by scaled leaf ideograms of nine equal width classes.

Kassaby and McLean (1985) performed three different multivariate techniques on the spectral variables for identification of the origins of lodgepole pine seeds by X-ray energy spectrometric determination of mineral profiles. Cluster analysis was used to explore grouping among different seed lots. Culster analysis separated the northern and southern groups from each other. Discriminant analysis confirmed clear separation between northern and southern groups.

Methods and Procedures

The study was conducted in the watershed of the Little South Fork of the Cache La Poudre River, approximately 35 kilometers west of Fort Collins, Colorado. Data were collected from 50 stands in lodgepole pine (*Pinus contorta latifolia* Engelm. and spruce-fir (*Picea engelmannii* Parry/*Abies lasiocarpa* (Hook) Nutt.) forests of the watershed. Information collected from stands included cover and density for vascular plants. Physical stand characteristics were aspect, slope, and elevation as well as a soil profile description, texture analysis, and an evaluation of surface and profile stoniness.

Data analysis involved application of McNaughton and Wolf's (1970) niche width index, principal component, and discriminant and canonical analyses (Kendall 1957, Seal 1964, Volland 1974). Principal component analysis was utilized to structure stands based upon cover and density data of understory species. The evaluation process was used to identify distribution tendencies expressed by understory species. Information obtained through principal component results was used to group stands that were then analyzed using discriminant and canonical analyses. Vegetative groups formed, using contrasting species, were then evaluated with indices of habitat as discriminant variables. Circular confidence intervals were placed around the canonical separation of vegetative groups to determine whether measured indices could be used to describe geographical or environmental distribution tendencies of selected species.

Results and Discussion

Principal component analysis showed that within lodgepole pine communities, six understory species cover and densities were effective in classifying stands (Table 1). In contrast, only two understory species were identified in stand structuring of spruce-fir communities (Table 1). Combined results of the two principal component analyses suggested that four dominant species of the major components have more or less distinguishable distribution characteristics within the study area. Evaluation of distribution characteristics of understory species began with McNaughton and Wolf's index. The complex gradient of elevation and aspect was ranked in general terms of increased moisture from lower to higher elevation to provide the environmental gradient of the index. Rankings were weighted by the species dominance as measured by species coverage within each individual stand. Index of habitat width for the species of buffaloberry (*Shepherdia canadensis* (L.) Nutt.), kinnikinnik (*Arctostaphylos uva-ursi* (L.) Spreng.); common juniper (*Juniperus communis* L.), and whortleberry (*Vaccinium scoparium* Leiberg.) are given in Table 2. A description of indices will be discussed separately for each species.

Buffaloberry

Buffaloberry had the lowest habitat width index as expressed by dominant understory species (Table 2). Narrowness of the index implied that the species was somewhat restricted in the range of sites that it occupied in the study area and that the species was relatively consistent in terms of its cover contribution on sites where it occurred. The species predominantly occurred within mid to lower elevations of the study area. Stands containing the species ranged in elevation from approximately 2438m (8000 ft) to 2865m (9400 ft) Buffaloberry expressed its largest and most consistent contributions of cover on the northern aspects. The overstory component of stands was consistently dominated by lodgepole pine with scattered occurrences of Douglas fir (*Pseudotsuga menziesii*, var. *glauca* (Beissn.) Franco.). Common understory associates of the species were common juniper and rose (*Rosa* L. spp.). Overstory of stands containing buffaloberry ranged in development from immature overstory that had higher cover and density values to mature stands with low tree densities.

Common Juniper

Relatively low habitat width measure of common juniper is somewhat deceiving in relation to dominant understory species of the lodgepole pine and spruce-fir communities. Deception arises from lack of a definable range of aspect and elevation in which common juniper expressed understory dominance. Table 2 displays absence of relatively large cover contributions by species in stands where it is observed. Common juniper was found in stands ranging in elevation from 2438m (8000 ft) to 3048m (10.000 ft). However, as indicated by

Table 2, this species exhibited relatively low cover values for most stands which resulted in the low habitat width measure. In general, the species appeared as either a condominant or subdominant species in the understory. The species was associated at mid and lower elevations with buffaloberry and kinnikinnik. Stands from higher elevations indicated that common juniper was an occasional associate of whortleberry. Common juniper occurred in understory of both spruce-fir and lodgepole pine communities, but had the greatest occurrance in mature stands of lodgepole pine.

Kinnikinnik

Kinnikinnik had the largest habitat width index of species generally associated with dryer elevations of the lodgepole pine forest (Table 2). The species was observed in stands ranging from 2438m (8000 ft) to 2956m (9700 ft) in elevation. Geographical distribution of kinnikinnik within the study area indicated that the species occurred on southern aspects at higher elevations, and northern aspects at lower elevations. However, occurrence of kinnikinnik on northern aspects at lower elevations was more of a reflection of lodgepole pine occurrence at lower elevations than a distribution characteristic of kinnikinnik. This relation occurred because sampling strategy restricted stand selection to lodgepole pine and spruce-fir forests, and consequently, the occurrence of some species (i.e., kinnikinnik) at lower elevations was not represented by the data collection process. Common understory associates of kinnikinnik are rose, common juniper, and golden banner (*Thermopsis divaricarpa* A. Nels). Overstory predominantly associated with the species ranged from immature stands of lodgepole pine to maturing stands of lodgepole pine.

Whortleberry

Whortleberry had the largest habitat width index of understory species studied. The species occupied the widest range of elevations and expressed the widest range of cover values in the data set (Table 2). Whortleberry occurred in both lodgepole pine and spruce-fir communities. Cover contribution of whortleberry to understory appeared relatively consistent on all aspects of higher elevations However, at lower elevations the species was encountered primarily on northern aspects. Understory associates of whortleberry included rose, common juniper, buffaloberry, and heartleaf arnica (*Arnica cordifolia* Hook.).

Discussion

Dominance of understory species at different aspects and elevations suggested that soil profile characteristics of stands might provide further discrimination between species. Kinnikinnik, buffaloberry, and whortleberry were selected for further analysis since their geographical distribution tendencies showed the least amount of overlap and, hence, the greatest potential for discrimination. Discriminant and canonical analyses were utilized in the analysis to measure effectiveness of soil profile attributes to discriminate between stands occupied by understory species. Vegetation groups were formed for analysis by listing stands that contained each of the individual species. Stands that contained two or more species were placed in each species group. As a result of the group formulation procedure, misclassification of stands within groups was determined by using understory dominance of a stand rather than initial group formation.

Table 3 illustrates the relation of soil profile attributes to individual species and the order of selection in the model. The model correctly classified 80 precent of the stands based upon understory domination by the species. Misclassifications predominantly occurred between stands dominated by kinnikinnik and buffaloberry since these species were often associated within close proximity to each other. Confidence intervals at the 95 percent level indicated that measured soil profile attributes can be used to discriminate between group means of whortleberry versus kinnikinnik and/or buffaloberry. In contrast, no significant difference ($P<0.05$) could be determined between kinnikinnik and buffaloberry groups.

Significant ($P<0.05$) separation of the whortleberry group does not imply that each stand within vegetative groups can be separated on the basis of these attributes. Group separation is based upon a representative average of soil profile attributes and does not take into account a species ability to compensate and overcome undesirable characteristics of a site.

Figure 1 provides a plot diagram of species separation expressed by the soil and duff attributes. The x axis of canonical separation accounted for 98 percent of total dispersion. The axis separated the stands that contrasted depth of decomposed and undecomposed duff layers. Remaining soil attributes were utilized in canonical separation, but their effectiveness was limited by the magnitude of their respective canonical coefficients. In general, the largest cover contributions of each individual species occurred in close proximity to the soil and duff mean of vegetative groups.

Results of the analysis are in agreement with the habitat width description for individual species. However, variability contained within vegetative groups indicated relative independence of the species to measured soil profile attributes of the stands.

Conclusions

The occurrence of the dominant understory species examined in this study was sensitive to aspect and elevation. Several understory species occurred under a variety of overstory compositions and expressed a relative independence to tree species dominance and density. Understory species, being shorter-lived than overstory species, provided a relatively sensitive indicator of suboptimal environmental factors that longer-lived species may tolerate through species compensation. Figure 2 summarizes distribution tendencies of the dominant understory species studied. Recognition of these tendencies by a natural resource manager can provide insight into the potential vegetation of a site. Statistical separation of vegetative groups, using soil profile characteristics, suggested a site delineation along a complex gradient expressing available soil moisture.

LITERATURE CITED

Barkham, J.P. and J.N. Norris. 1970. Multivariate procedures in an investigation of vegetation and soil relations of two beech woodlands, Cotswold Hills, England. Ecology 51:630–639.

El-Kassaby, Y., and J.A. McLean. 1985. Identification of the origins of lodgepole pine seeds by X-ray energy spectrometric determination of mineral profiles. Forest Sci. 31:539–551.

Goodall, D.W. 1953. Objective methods for the classification of vegetation. II. Fidelity and indicator value. Austral. J. Bot. 1:434–456. Horton, I.F., J.S. Russel, and A.W. Moore. 1968. Multivariate-covariance and canonical analysis: a method of selecting the most effective discriminators in a multivariate situation. Biometrics 24:845–858.

Kendall, M.G. 1957. A Course in Multivariate Analysis. Griffin, London. 185 p.

McNaughton, S.J. and L.L. Wolf. 1970. Dominance and the niche in ecological systems. Science 167:131–139.

Newham, R.M. 1968. A classification of climate by principal component analysis and its relationship of tree species distribution. Forest Sci. 14:254–264.

Potts, B.M., and J.B. Reid. 1985. Analysis of a hybrid swarm between *Euclyptus risdonii* Hook. f. and E. amygdalina Labill. Aust. J. Bot. 33: 543–562.

Potts, B.M., and J.B. Reid. 1985. Variation in the *Euclyptus gunni-archeri* complex. I. Variation in the adult phenotype. Aust. J. Bot. 33:337–359.

Seal, H.L. 1964. Multivariate Statistical Analysis for Biologists. Methuen and Co., LTD., London. 209 p.

Volland, L.A. 1974. A multivariate classification of lodgepole pine type in central Oregon with implications for natural resource management. Ph.D. Thesis. Colorado State University, Fort Collins. 250 p.

Walker, B.H. and C.F. Wehrhahn. 1971. Relationship between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. Ecology 52:85–95.

White, E.H. and D.J. Mead. 1971. Discriminant analysis in tree nutrition research. Forest Sci. 17:425–427.

Table 1: Eigenvectors using the understory species[1] cover and density attributes from the Lodgepole pine and Spruce-fir communities.

	Vector 1 coefficients	Percent of vector accounted for	Vector 2 coefficients	Percent of vector accounted for
Lodgepole Pine				
Buffaloberry cover	.4445	19.75	−.7403	54.80
Common juniper cover			−.1659	2.75
Wortleberry cover	.4692	22.01	.5964	35.57
Kinnikinnik cover	−.6831	46.66	−.1308	1.71
Whortleberry density	.1492	2.23	.1876	3.52
Kinnikinnik density	−.2298	5.28		
Percent total		95.93		98.35
Eigenvalue using 46 cover and density attributes	51.82		49.93	
Percent of trace accounted for	31.72		30.56	
Spruce-fir				
Whortleberry cover	.9633	92.79		
Whortleberry density	.2586	6.68		
Percent total		99.47		
Eigenvalue using 18 cover and density attributes	364.7			
Percent of trace accounted for	91.94			

[1] Species accounting for one percent or more of vector.

Table 2: Index of habitat width for selected species and their average cover contribution at various elevations.

Species	Buffaloberry		Kinnikinnik		Common Juniper		Whortleberry	
Index	117		183		124		653	
Aspect	S	N	S	N	S	N	S	N
3200 (10,500)[1]							16[2]	35
3048 (10,000)							35	35
2895 (9,5000)			3		7	2		30
2743 (9,000)	.4		10		5	4	1	15
2591 (8,500)		11	10	14		4		14
2438 (8,000)		14		4		5		4

[1] Elevation in 152-m (500-ft) increments.

[2] Species cover component in percent.

Table 3: Reduced model; discriminant function coefficients for three groups and canonical equations with group mean evaluation.

Discriminant function	Decomposed duff	Undecomposed duff	A horizon	Percent silt	A & B horizon	Constant	Mean evaluation ±1 confidence interval		
							Whortleberry	Kinnikinnik	Buffaloberry
Whortleberry (22 cases)	.3769	1.921	−.2517	1.2676	.8973	−26.41			
Kinnikinnik (11 cases)	.9438	2.455	−.1623	1.369	.9595	−31.24			
Buffaloberry (7 cases)	−.8897	2.638	−.1588	1.428	.9741	−33.67			
Order of Selection	2	4	1	3	5				
Canonical Equation x axis	−.6663	.3136	.0466	.0647	.0351	−2.888	−.875 ±.4552	1.02 ±.7686	1.15 ±1.241

[1] Radius of confidence interval determined at .05 level of significance.

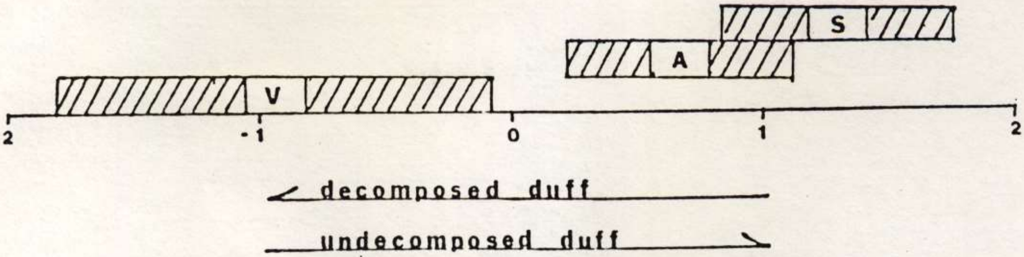

Figure 1. Canonical separation of three vegetative group means utilizing soil and duff attributes. V–whortleberry, 22 cases; A–kinnikinnik, 11 cases; S–buffaloberry, 7 cases; ///–identifies the placement range of stands forming the individual groups.

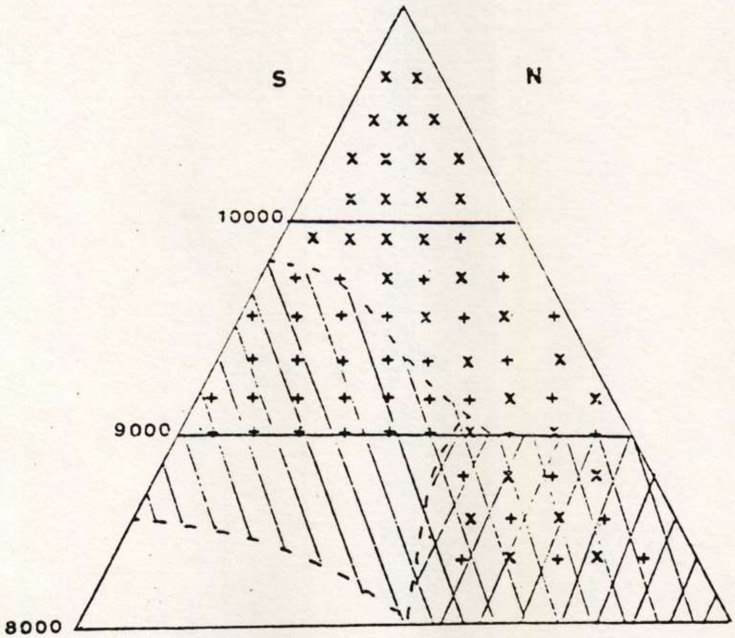

Figure 2. Plot diagram of the distribution tendencies of five understory species in the study area. x–whortleberry and heartleaf arnica; +–common juniper; \\\–kinnikinnik; ///–buffaloberry.