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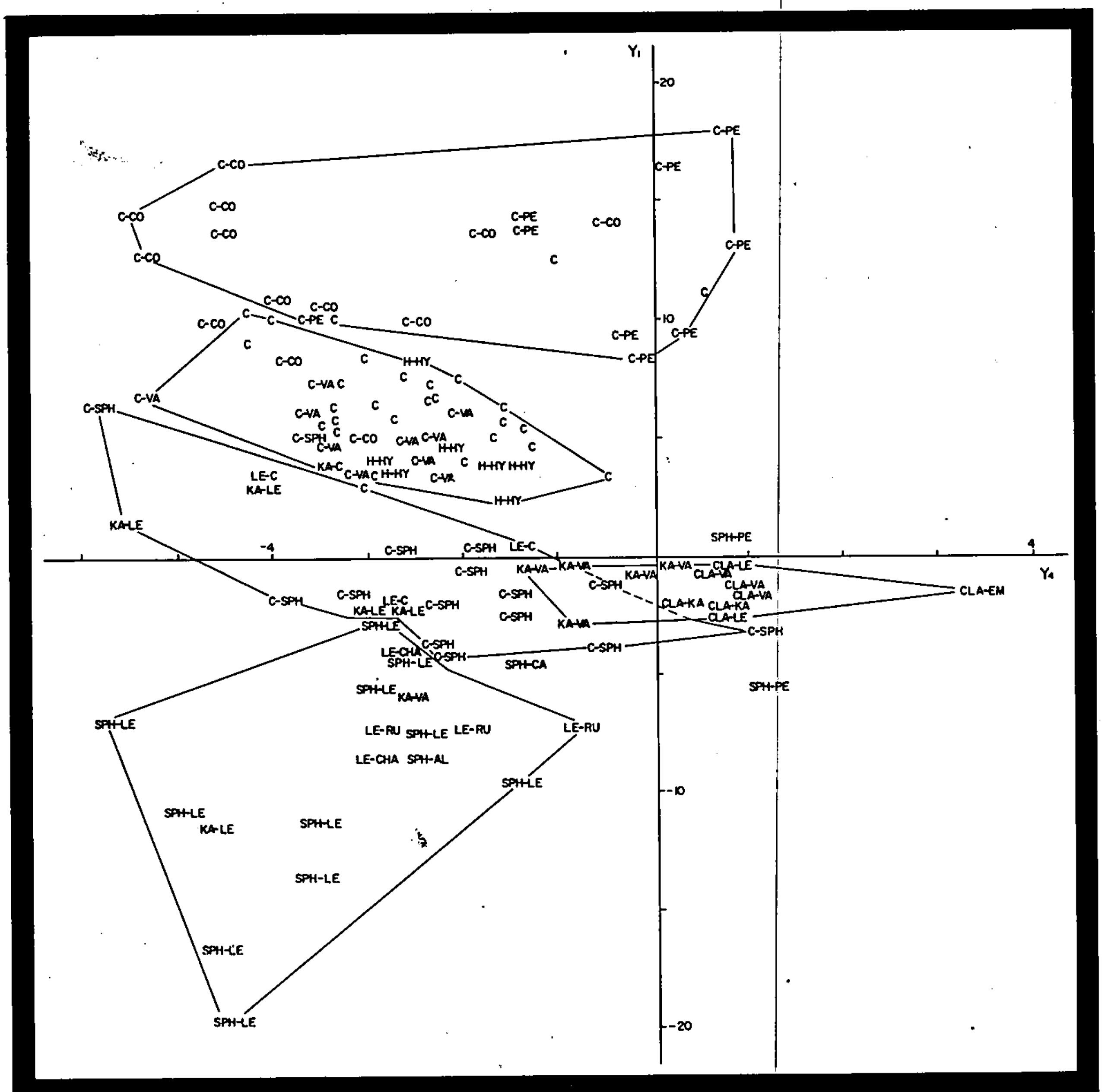
APPLICATION OF MULTIPLE REGRESSION AND PRINCIPAL COMPONENT ANALYSIS TO GROWTH PREDICTION AND PHYTOSOCIOLOGICAL STUDIES OF BLACK SPRUCE STANDS

by Gilles Vallée and Gerald L. Lowry



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* Project realized in collaboration with the Pulp and Paper Research Institute of Canada.

SUMMARY

This report demonstrates the suitability of using multiple regression and principal component analyses for growth prediction and phytosociological studies in black spruce forests of eastern Canada.

The data come from 125 black spruce stands located in the Boreal forest of Canada from Newfoundland to western Ontario. The observed factors in this study are: dominance of species and species groups, stand density, soil moisture regime and site index.

The prediction of site index is satisfactory using the dominance of species and species groups in multiple regression. Principal component analysis shows some possibilities of application for the identification of broad site quality classes. Further study is needed to perfect the vectorial ordinations before this method can be used for prediction purposes.

The classification of forest stands as to types and associations seems to be relatively simple with the component analysis. For application to field conditions each region should be studied separately in order to increase the precision of the vectorial ordinations.

RÉSUMÉ

Cette publication démontre les possibilités d'utilisation de la régression multiple et de l'analyse des composantes principales pour la prédiction de l'indice de fertilité et pour l'étude phytosociologique des forêts d'épinette noire de l'est du Canada.

Les données proviennent de 125 peuplements d'épinette noire répartis dans la forêt boréale du Canada, de Terre-Neuve à l'ouest de l'Ontario. Les facteurs considérés dans l'étude sont: la dominance des espèces et des groupes d'espèces, la densité des peuplements, le régime hydrique du sol et l'indice de fertilité des stations.

L'indice de fertilité des stations est bien estimé à l'aide de régressions multiples basées sur la dominance des espèces et des groupes d'espèces. L'analyse des composantes principales indique que cette méthode pourrait servir à l'identification de grandes classes de fertilité, mais au préalable des études plus poussées sont nécessaires pour préciser les ordinations vertorielles.

L'analyse des composantes principales peut être utilisée pour classifier les peuplements en associations forestières et types forestiers. L'application générale de cette méthode nécessiterait une étude particulière de chaque région en vue d'accroître la précision des ordinations vertorielles.

APPLICATION OF MULTIPLE REGRESSION AND PRINCIPAL COMPONENT ANALYSIS TO GROWTH PREDICTION AND PHYTOSOCIOLOGICAL STUDIES OF BLACK SPRUCE STANDS

by G. Vallée[1] and G.L. Lowry[2]

FOREWORD

In its forest soil-site studies the Pulp and Paper Research Institute of Canada has been investigating the effect of soil and related site factors on the growth of Canadian pulpwood species with a view to developing methods of increasing production. The first phase has dealt with black spruce in eastern Canada. An attempt has been made to (a) determine on a statistical basis the contributions made by various soil physical and chemical properties to the growth and yield of representative stands, (b) test the value of present physiographic and phytosociological forest classification systems for growth and yield prediction, and (c) determine the interrelationships and the possibilities of using these measurements to predict growth and yield. The results on black spruce have been published in a series of reports[3]. This publication covers the use of principal component and multiple regression analyses for phytosociological studies, classification

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of eco-systems and growth prediction of black spruce stands. Dr. Vallée has been associated with this project since 1962. He was particularly interested in the use of vegetation for evaluating site fertility. This manuscript was originally prepared for publication by the Pulp and Paper Research Institute of Canada. However, due to a recent change in research emphasis this report has been released by the Institute for publication by the Research Service of the Department of Lands and Forests of Quebec.

[3] LOWRY, G.L., 1964. *Forest soil-site studies. I. Objectives, sampling, preliminary results on black spruce.* W.R.I. 154. P.P.R.I.C.

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PART 0

GENERAL CONSIDERATIONS

0-1 INTRODUCTION.

Because of the qualitative nature of phytosociologic units such as forest vegetation types or other plant groups, their use to evaluate site fertility is difficult. Furthermore, between discrete units there is a zone of gradation which must be assigned in the proper proportions to the neighbouring units in mapping site fertility on a regional basis. The result of including these gradation zones increases the amount of variation within each unit.

Many of the present descriptive methods of vegetation classification are partly subjective. To avoid such subjectivity some phytosociologists have calculated coefficients of similarity or have analysed statistically, relationships between the various plant species. Dagnelie[23] employed principal component analysis and factorial analysis on the interspecific relationships for phytosociologic and ecologic description and for classification of site fertility. Similarily, Ashton[1] used an ordination method in studying the correlation between site productivity and soil composition. Kinloch and Mayhead[63] used factorial analyses in classifying site fertility of plantations.

In the present study principal component analysis was employed to classify the black spruce forest types and associations and for estimating site quality. The method used here of estimating the dominance of groups of species appears to improve the correlations with site index as compared with the individual species. These correlations were then compared with the results obtained from principal component analysis.

0-2 OBJECTIVES.

The primary objective of this study is to find a practical way to evaluate site fertility in pure black spruce stands (*Picea mariana* Mill. BSP.), by using the vegetation as it occurs. The method of site evaluation should be simple and inexpensive to apply. The vegetative factors (species and species groups) considered should be easy to identify and to measure.

A secondary objective is to check the usefulness of certain methods of statistical analysis in phytosociological classification of forest areas.

These objectives will be developed in three parts:

Part 1 : The diversity of vascular flora, the forest types and the distribution of species cover will be determined directly from the original data.

Part 2 : The usefulness of statistical analysis in phytosociological studies of floristic lists will be investigated and especially the applicability of principal component analysis to the classification of the black spruce forest types and associations.

Part 3 : Principal component and multiple regression analysis of floristic factors will be examined to determine their relative precision in estimating site quality.

0-3 LITERATURE REVIEW.

Only a general review of the principal work which has been done in Canada in phytosociologic or phyto-ecologic forest classification is presented here. Ilvessalo[58], Rousseau[83,84] and Bellefeuille [2,3] defined some forest types of indicator plants, in accordance with the concepts of the Finnish typologists' school of Cajander[13-21]. Heimberger[48,49] classified certain forests in a similar manner using soil analysis. Likewise, Ray[80], Kajula[64] and Spilsbury and Smith[86] demonstrated a relationship between the forest types and wood production. In general these workers gave more importance to the vegetative characteristics than to those of the site.

Hills[50-55], classified the forest sites by the lesser vegetation, moisture regime and soil permeability, with these last two factors being linked to the physiognomy of the region being mapped. This classification used the concepts of the phytogeographic-physiognomic school of Humboldt[56,57], von Marilaun[90], Grisebach[46] and Raunkiaer[78].

Lafond[68-70] and Linteau[74], combined the floristic analysis phase of the Braun-Blanquet system[4-12] with the site type system of the Finnish school, and in classifying the forests took into account certain ecologic factors (soils, slopes, exposure, etc.) so as to get a better definition of the phytosociologic units. These authors demonstrated that each " site type" corresponded to a given wood production and therefore to a certain fertility the variation of which was small inside a given region. However, our studies indicate that this variation is quite large for a given "site type" when considered over the range of eastern Canada.

Dansereau[25-36] has studied the vegetation grouping of the St. Lawrence region following the Braun-Blanquet system but without considering the relationships of soils to vegetation and other ecologic factors. Grandtner[41-45], Jurdant[59-62], Lemieux[72,73], Damman[24], Ladouceur[65] and others used the method of floristic study of Braun-Blanquet together with the ecologic factors controlling the development of phytosociologic units to demonstrate the usefulness of these ecologic types as mapping units. This permitted a better understanding of ecology and the dynamics of the vegetation and the soils.

This last method presents many advantages in forestry as has been indicated by Dagnelie[22,23], Manil[76], Richard[81,82] and Duchaufour[39]. Because these units represent sites of different wood production and different management requirements, we may evaluate approximate potential productivity of a forest and locate the silvicultural problems within it. This system promises to be a good working instrument for practising and research foresters.

There is reason to believe that more objective and simpler identification of the phytosociologic units may be achieved by the application of more advanced mathematical techniques. Also, by considering the vegetational factors as continuous variables, more precision of estimating site quality should be possible.

0-4 METHODS.

0-41 SAMPLING AREA.

The sampling area was confined to the Boreal coniferous forest, that is to say the basam fir (*Abies balsamea* Mill.) and black spruce domaine as defined by Grandtner[42]. One hundred and twenty-five sample plots were located from western Ontario to the Atlantic ocean. Figure 1 shows the location of the 25 study areas.

0-42 SELECTION OF SAMPLE PLOTS.

In each study area, five pure black spruce stands were selected. Each stand represented a " site type"* or an homogeneous floristic surface. The five sample plots were selected to represent a range of fertility and to include the more common ecologic sites of the region.

The stands selected were regular and even-age with little evidence of recent mortality and were of fire origin. Stand age varied, in general, between 30 and 130 years.

0-43 PLOT DESCRIPTION.

Each sample plot was described (see Lowry[75]) according to its slope, topography, exposure, latitude, longitude, vegetation, soil profile characteristics and stand conditions. Soil and foliage samples were taken for laboratory analysis. In addition, stem analysis was made to determine current and average cubic foot yields. This report considers only the vegetation and some selected ecologic factors.

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* The site type is defined as: "A group of stands which are sufficiently homogeneous as to the tree species which constitute them and as to the dominance of certain shrubs, herbs, mosses and lichens, to produce certain quantities of wood, to have certain rates of growth, to have an origin and final evolution which may necessitate a particular type of silviculture and management" (Lafond[68]).

0-44 METHOD OF VEGETATION STUDY.

0-441 The ecologic factors used.

Site fertility, soil moisture regime and the tree cover were used to study the dominance structure of selected species in black spruce stands.

0-4411 Fertility.

As used herein, fertility is based upon the average site index of the black spruce stand. For each plot, the total height and stump age of 10 dominant and codominant trees were measured and site index was determined from the height-age curves of Plonski[77] at 50 years. The average site index for the plots was further consolidated into fertility classes as follows:

Site index class in feet	Fertility class
45 - 54.9	I
35 - 44.9	II
25 - 34.9	III
15 - 24.9	IV
2.5 - 14.9	V

0-4412 Soil moisture regime.

The scale used for moisture regime was taken from Hills[51] and was suitable for use, without modification, in computer analysis due to the small number of sample plots in certain moisture regimes, it has been neces-sary to use, in some of the studies, a grouped site moisture classification with fewer divisions, as follows:

Moisture regime	Site moisture class	Definition
0	(Euxeric	Very dry to dry
1	(Subxeric	Somewhat dry to fresh
2	(	Fresh
3	(Mesic	Very fresh
4	(	Very fresh to moist
5	(Subhydric	Moist
6	(	Very moist
7	(	Very moist to somewhat wet
8	(Euhydric	Wet
9	(	Very wet to saturated

0-4413 Cover of the tree stratum.

The degree of cover of the tree stratum affects the light intensity under the forest. As a result, the dominance of species composing the lower strata may be affected. In order to quantify the tree cover, the following area percentage classes were adopted: 0 to 20, 21 to 40, 41 to 60, 61 to 80 and 81 to 100.

0-442 Floristic list by species.

The list of all species for each plot was made by estimating the dominance and sociability of each species on an area of approximately 1/10 acre. In the case of tree species, the sample area was somewhat larger in order to ensure a good estimate. Only the dominance data was used in this study.

To properly explain the present study it is necessary to define dominance with regard to phytosociology. Dominance is the amount in volume or area, occupied by the individuals of the same species relative to the amount of the whole sample plot (Guinochet[47]). In this particular case, the dominance "is the degree of cover of all the individuals of the same species or of a species group relative to the area of the sample plot".

The scale of dominance (D) utilized was:

D	Percent of cover of the species	Median percent of the class
0	0%	0%
1	+0% to 5%	2.5%
2	6% to 20%	12.5%
3	21% to 40%	30.0%
4	41% to 60%	50.0%
5	61% to 80%	70.0%
6	81% to 100%	90.0%

The scale as presented above is convenient for statistical analysis of the data. The median percentage of each dominance class was used to compute the "dominance percent" of the species by class of ecologic factors.

The abbreviations as proposed by Day[37] were used where possible. A list of the principal species identified in this study appears in Appendix I along with the abbreviation for each.

0-4421 Strata.

As the floristic list was compiled, separate estimates of the percentage of cover of the tree, shrub, herb and moss strata were made. These are defined as follows:

Tree stratum : Comprises the tree species making up the crown canopy and dominating all the other species of the stand.

Shrub stratum: Comprises shrubs and dwarf shrub species. It is more or less the intermediate stratum relative to the herbaceous carpet and the overstory trees. The height varies generally from 6 inches *(Vaccinium spp.)* to 12 feet *(Alnus spp.)*.

Herb stratum : Comprises certain dwarf shrubs and the herbs, grasses, sedges and pteridophytes of which the height varied from prostrate up to 1.5 feet.

Moss stratum : Comprises the moss, liverwort and lichen species growing near the soil surface.

These definitions of the strata permit grouping the species so that their above-ground vegetative parts belong to the same competetive three-dimensional space.

0-443 Floristic list by species groups.

From a preliminary evaluation of the species lists of the first forty plots it was found that within any one stratum, the dominance of certain species was related to site fertility. This dominance varied with the ecology as well as the fertility of the site. Thus, a wet site with low fertility was found to be dominated by the Sphagnum species, whereas a dry site with low fertility was dominated by reindeer moss (CLA) species. On the other hand, even under similar ecological conditions, one species could have a higher dominance than another species due to a fortuitous or competitive effect. These relationships were checked by correlation analysis.

One objective in this study was to determine the relationship between species dominance and site fertility. It was found desirable to place certain species together into groups where they occurred in the same stratum and where they had the same pattern of dominance. By so doing, it was possible to estimate the dominance of the species group directly rather than by the addition of single species. The percentage of cover of the species groups was estimated with satisfactory precision (± 1 per cent) by using a 30 inches by 30 inches quadrat, with sides divided into 5 equal parts.

The percent of cover of a species group was an arithmetic mean of twenty quadrat estimates, which in all cases gave a stable mean. The twenty quadrats were distributed in the sample plot along two lines, intersecting at 90° and passing through the center of the plot. Ten quadrats were taken on each line with a uniform spacing between them. This floristic list was made for 75 sample plots and the species groups were composed as follows.

Variables	Stratum	Component species (see Appendix I)
X_1	Tree	BEp - POt - POb - PRp - SOa - ACsp - ACr - BEl
X_2	Shrubs	LEg - KAa - KAp - CHAc - VA - RHc
X_3	Herbs	CHh - VAo - VAv - EMn - CA - CLIb - SMt - EQ
X_4	Herbs	COc - LIb - ARn - ASm - ASl - ASc - SOLm - PTa - MIn - PEp
X_5	Mosses	Cs - Du - Df - Ds - Hc
X_6	Mosses	SPH - CLA - HYp

PART 1

DIVERSITY OF VASCULAR FLORA, THE SITE TYPES AND THE DISTRIBUTION OF SPECIES COVER ACCORDING TO CERTAIN SITE FACTORS

1-1 DIVERSITY OF THE VASCULAR FLORA.

1-11 VARIATION WITHIN THE STUDY REGION.

The study region comprised a very large area in which soil, latitudinal and climatic differences may have affected the diversity (number of species) of vascular flora. Also the last glaciation may have influenced the distribution of the flora within the study area. In order to determine the magnitude of this variation the total number of different vascular species recorded for the five study plots at each location were added together and the total value is shown in figure 2.

1-111 Results.

In total, 167 different vascular species were identified. From figure 2 it is apparent that, from west to east, the number of vascular species per study area decreased.

The study areas may also be grouped into three climatic-geologic regions as shown in figure 2:

A. The region influenced by clay soil of Ontario-Quebec with 124 vascular species identified.

B. The granitic soil region of Ontario, Quebec and New Brunswick with 87 vascular species identified.

C. The granitic soil region to the east of the 65th meridian which comprises a part of the Quebec North Shore, Labrador and Newfoundland, with 49 vascular species identified.

1-12 VARIATION IN NUMBERS OF VASCULAR SPECIES BY SITE CONDITIONS.

In order to gain a better understanding of the occurence of the many plant species, plots were stratified according to fertility, moisture regime and tree strata density. The result of this stratification are listed in tables 1, 2 and 3.

1-121 Results.

A. The highest number of vascular species occured on the most fertile sites (table 1). Even though site fertility is related, to a certain degree, to density of the tree stratum, it would appear that this density (table 3) is not closely related to the number of vascular species present on the site.

B. The maximum average number of vascular species is found on the sample plots of mesic and hydric moisture condition (Table 2). It was found that the herb stratum, in particular, contributes most toward the average number of species by fertility, moisture and tree density class. The tree and shrub strata generally contain a fixed group of species but with a variable dominance. However the herbaceous species are more numerous on fertile and moist sites than on the infertile and dry sites.

Table 1. Average number of vascular species by fertility class.

Site index class	Fertility class	Number of sample plots	Average number of vascular species
54.9 - 45	I	11	26
44.9 - 35	II	34	22
34.9 - 25	III	34	13
24.9 - 15	IV	30	12
14.9 - 1	V	16	14

Table 2. Average number of vascular species by moisture condition.

Site moisture		Number of sample plots	Mean number of vascular species	
Class	Regime		by moisture regime	by site class moisture
Euxeric	0	14	12	12
Subxeric	1	11	13	14
	2	29	15	
Mesic	3	20	19	19
	4	12	20	
Subhydric	5	4	22	18
	6	8	16	
Euhydric	7	6	22	17
	8	18	16	
	9	3	16	

Table 3. Average number of vascular species by class of tree cover.

Class of tree cover	Number of sample plots	Average number of vascular species
1 - 20%	5	17
21 - 40%	23	12
41 - 60%	24	16
61 - 80%	41	16
81 - 100%	32	20

1-13 CONCLUSION.

Three floristic regions, different as to soil and geography, are characterized by differing numbers of vascular species. In this study it was found that the diversity of the vascular flora decreased from west to east of the sampling region. This confirms the findings of LaRoi[71] who gives a maximum number of species to the north of the Great Lakes region with a minimum in the Maritime provinces and in Alaska. Furthermore the great geologic formations (clay and granite morains) seem to exhibit a strong influence on the presence of vascular species.

The fertility and moisture regime of the site were related to the number of vascular species present. The density of the tree stratum and therefore light intensity did not appear to be closely associated with the number of vascular species on the site. However, with a decrease of light intensity a decrease in dominance was noted for many species.

1-2 BLACK SPRUCE SITE TYPE AND ITS ASSOCIATIONS.

1-21 IDENTIFICATION OF ASSOCIATIONS AND SITE TYPES.

From the floristic list by species and using the site type description of Linteau[74], Lafond[68] and Damman[24] each sample plot was identified as to its site type and association. Black spruce associations, site types and moisture regime are listed in Appendix II with their frequency by site index class.

The association as used in Appendix II is in the same context as given by Linteau[74] and is relative to the importance of the defined vegetation strata, the type of the cover and the tree composition. In part 2 (which follows) the principal component analysis of inter-specific relations suggests that an other association exist in addition to those described by Linteau[74]. This new association (Peat moss and herb) is included in Appendix II.

1-22 CONCLUSION.

For the same site type, the variation in site index is quite large and is distributed, in general, in two or more fertility classes (see Appendix II). For example, the site index of the Calliergon type, which is easy to identify, is most strongly represented in fertility classes II and III but also occurs in classes I and IV. This agrees in part with the conclusion of Linteau[74] who stated:

> "Site types and plants were found to be consistent throughout this territory (Rowe's section B-1,[85]) which covers more than 75 000 square miles. Supporting the same communities but lower in productivity are a few isolated spots in the higher mountains of Laurentide Park. That part situated east of Rocky River (67° W. longitude) along the Gulf of St. Lawrence was also found to be poorer. In both areas, the length of the growing season is noticeably shorter than in the rest of the section."

This would agree with the findings presented here. Also, the site types as described by Lafond[68] and Linteau[74] generally occur throughout eastern Canada, but at a different fertility level depending on the particular region. In a later section (3-2) comparisons will be made of the site index estimation of Linteau[74] with that computed by multiple regression.

1-3 DISTRIBUTION OF THE COVER OF SPECIES AND STRATA IN BLACK SPRUCE STANDS AS RELATED TO SITE FERTILITY, SOIL MOISTURE REGIME AND COVER OF THE TREE STRATUM.

The study of the cover distribution of the strata and the species will allow a description of the structure of black spruce stands. These structures are shown in figures 3 and 4 by strata and by species groups as related to site fertility, soil moisture regime and cover of tree stratum.

The mean percent of cover of the species groups and of the strata was an arithmetic mean of the plot data. The data from the quadrat method were used for the species groups (see Appendices III, VII and VIII). The mean dominance percent of selected species by fertility class, by moisture regime class and by percent of cover of the tree stratum is presented as additional information (see Appendices IV, V, VI).

Having established the large variation of fertility within a given site type, a test was made to check the relationships between site fertility and the dominance of species and species groups. Many trials with respect to climatologic or vegetative norms (climax) were attempted by grouping the plots and comparing the mean site index by dominance class for various species and species groups. This part of the study was carried out to attain a better precision in applying statistical methods in the estimate of site fertility. Conclusions of this section will be based on the data of the total number of plots.

1-31 RESULTS AND DISCUSSION.

In studying the relationships between site fertility and dominance of species and species groups, one region appears to differentiate itself from the rest of the study area. This region lies east of the 65° meridian and will be called the Atlantic region. The area to the west will be designated as the Continental region. It was found that site indices were lower in the Atlantic region and as a result fertility class I was not found. This general observation was also made by Linteau[74]. A more intensive study of the Continental region would be expected to identify still other areas whose vegetation - site fertility relationships were different.

The strata curves of figure 3 show the cover structure in pure black spruce stands. At fertility classes I and II the tree cover is at its maximum and the herb cover is nearly the same as the shrub cover. The black spruce associations with herbs and hypnum or hypnum alone as described by Linteau[74] are located at these fertility classes, at moisture regime 3 to 6 (mesic and subhydric classes), and at a tree cover of 61 to 100 percent.

Figure 4 shows the principal species composition from the curves of species groups. Appendices IV, V and VI give additional data. The reader must remember that groups X_1, X_4 and X_5 composed principally of paper birch (BEp), trembling aspen (POt), bunchberry (COc), twin-flower (LIb), wild sarsaparilla (ARn), large-leaved aster (ASm), Schreber's moss (Cs) and plume moss (Hc), are particularly important in these associations even though groups X_1 and X_4 are numerically small. At fertility class III and the neighbouring part of class IV the shrub and moss strata assume more importance as opposed to the herb stratum.

The black spruce association with mosses and dwarf shrubs of Linteau[74] is the principal community at a moisture class of subxeric (1, 2) or subhydric (6, 7) and a tree cover class between 41 and 60 percent. The ericaceous shrubs such as sheep laurel (KAa), swamp laurel (KAp), leather leaf (CHAc), Labrador tea (LEg) and *Vaccinium* species (VA) of group X_2 and Schreber's moss (Cs) of group X_5 are representative of this association. Depending on the soil moisture, KAa and VA seem to be more important on subxeric sites where reindeer mosses (CLA) form a mosaic with Cs. However, LEg, CHAc and KAp appear more often on subhydric sites with patches of sphagnum moss (SPH).

At fertility classes IV and V the shrub stratum is as important as that of trees, and the herb stratum reaches another maximum at V. The moss stratum appears to be slightly more dense at these classes of fertility but particularly on hydric sites of moisture regime 7, 8 and 9. This condition applies also to the shrub and herb strata. The species composition of the herb stratum in classes IV and V is different than in fertility classes I and II even though the percentage of cover is similar. In figure 4 snowberry (CHh), false solomon's seal (SMt), sedge (CA), small cranberry (VAo) and mountain cranberry (VAv) of group X_3 are the most important species, particularly on hydric sites. The SPH species of group X_6 and the LEg, CHAc and KAp species of group X_2 characterize more the hydric sites where the sphagnum moss and dwarf shrub black spruce association of Linteau[74] is found. On the contrary, *Cladonia* (CLA) species of group X_6 and KAa and VA of group X_2 are more representative of the xeric sites, with CHh as the principal species of group X_3, where the lichen and dwarf shrub black spruce association is located. A summary table of these observations appears below.

Table 4. Summary of the black spruce associations as related to site fertility, moisture regime, tree cover and principal species groups.

Considered factor	Black spruce association*				
	Herbs and hypnum	Hypnum	Mosses and dwarf shrubs	Lichens and dwarf shrubs	Sphagnum and dwarf shrubs
Fertility class	I, II	II-III	III-IV	III-IV-V	III-IV-V
Moisture regime	2,3,4,5	1,2	1,6,7	0,1	7,8,9
Cover of tree stratum (%)	61-100	61-100	41-60	21-40	0-40
Principal species species groups	X_1 X_4 X_5	X_5	X_2 X_5 X_6	X_2 X_3 X_6	X_2 X_3 X_6

* Sphagnum and herbs association has been omitted due to insufficient samples for proper characterization.

With regard to the site fertility-species dominance (cover) relationship, two distinct regions appear in our sampling: the Atlantic and Continental region respectively located to the east and west of the 65° meridian.

With the strata and species groups cover and the dominance percent of the species it is possible to explain and situate the black spruce associations of Linteau[74]. Species dominance for a fertility and moisture regime class seems to have significance in characterizing site fertility.

PART 2

UTILIZATION OF STATISTICAL ANALYSES IN PHYTOSOCIOLOGICAL STUDIES OF FLORISTIC LISTS

2-1 INTRODUCTION.

In the preceding part a direct analysis was made of the species groups and species alone by the distribution of the dominance for certain site factors.

The use of correlation analysis between the species dominance or of species dominance with site factors is another way to study the floristic lists, in order to define some species groups characterizing certain ecologic conditions.

In the first part of this section the correlation coefficients between the dominance of the species and certain site factors will be considered directly. The second section will consider the indirect study of the correlation coefficients. Linear correlation will be used for comparative purposes even though curvilinear relationships would sometimes be more nearly correct. Only 35 of the 187 species identified were retained for this study because of the importance of their dominance in the black spruce stands. (See Appendix IX).

2-2 STUDY OF INTER-SPECIFIC AND SPECIES-SITE FACTOR RELATIONSHIPS.

This study applies to the total study region, since the modification of correlation coefficients occasioned by combining the Atlantic and Continental regions has little importance at this stage.

One may consider the correlation coefficients as quantitative entities to demonstrate whether or not a close relationship exists between two species or between species and site factors. Also, it may be used in a qualitative way. For example two species of which the dominance has the same pattern with a given factor will have nearly the same correlation coefficient with this factor.

One way to compare the correlation coefficients is to represent the species in a system of ordination* taking two frequent species or two factors for axes. The ordinates of the species are the correlation coefficients of the species dominance with each of the two variables defining the axes. (See Figures 5, 6, 7, 8 and Appendix IX). In this way the species having a similar pattern, with respect to the ordinates, will appear together in the same part of the graph. Afterwards, it may be possible to identify the ecologic significance of this grouping.

After a close study of four particular ordinations it appears that each of these supply additional and complementary information. This permits the formation of species groups from the correlation coefficient matrix (Appendix IX). These ordinations are defined as follows by their correlation coefficient axes identification: Site index and cover of tree

* Ordination is used here as a coordinate system.

stratum (Figure 5), site index and moisture regime (Figure 6), dominance of *Calliergon schreberi* and *Sphagnum spp.* (Figure 7) and dominance of *Cladonia spp.* and that of *Sphagnum spp.* (Figure 8).

2-21 RESULTS AND DISCUSSION.

a) The spacial ordination of the species relative to the correlation coefficient of their dominance with site index and that with the cover of tree stratum (Figure 5) reveals that the dominance of *Vaccinium spp.* (VA), *Kalmia angustifolia* (KAa), *Ledum groenlandicum* (LEg) and *Cladonia spp.* (CLA) is more dependent on the opening in tree cover than on site index, whereas the dominance of *Hypnum crista-castrensis* (Hc) and *Hylocomium proliferum* (HYp) depends on the closure of the tree cover.

The site index and cover of the tree stratum (Appendix IX) are moderately well correlated (r = 0.55). This means that on fertile sites one would find black spruce stands with higher than average density. If the dominance of species is correlated significantly with only one of these two factors then a doubtful or spurious relationship would be suspected. For example COPg and ROa dominance is significantly correlated with site index but not with tree cover. This indicates that species dominance can be important on fertile sites but not necessarily in high density stands. Therefore, the dominance of these species seems to be depressed by a dense tree cover or by some other factor. Using this principle two groupings of species can be formed with a dominance having a significant correlation coefficient ($r \geq 0.16$) with site index and tree cover ($p = 0.05$). The first grouping, correlated positively, is composed of the following species listed by strata:

Tree stratum : BEp, POt

Shrub stratum : SOa, DIl, VIp

Herb stratum : COc, TRb, MAc, LIb, ARn, ASm, PTa, MIn, PEp

Moss stratum : Cs, Hc, Du.

The second grouping, correlated negatively, is composed of the following species listed by strata:

Shrub stratum : CHAc, KAp, LEg, KAa

Herb stratum : VAo, CHh, SMt, CA

Moss stratum : SPH, CLA.

The ordinations of Figures 6, 7 and 8 give even more information on the species grouping. For example, when it occurs that the dominances of two separate species are correlated positively it means that the degree of cover of one of the species increases while the other species increases also. However, they must occur on the same sites. If two species never occur together, the relationship between their respective dominance will not exist. If the relationship is negative we suspect an antagonistic association. This means that the strong dominance of a given species would suggest a suppression in the dominance of the other and consequently these species characterize some opposite or different sites where their cover will be maximum. A positive relation means that the dominance of two species increases in parallel while they occupy the same sites characterized by them, this could be called an attractive association. A low positive correlation between two species is interpreted as a mediocre degree of association.

The species, *Calliergon schreberi* (Cs), *Sphagnum spp.* (SPH) and *Cladonia spp.* (CLA) represent three basic elements of the five great black spruce associations as defined by Linteau[74]. The ordination of the species relative to Cs, SPH and CLA suggests some groupings of species which are characteristic of certain moisture regime classes and black spruce associations of Linteau[74]. A careful study of Figures 6, 7 and 8 reveals that the level of significance of the correlation of the coefficient ($p = 0.05$), is not necessarily the only base on which to select species groupings. The proximity of certain species in the ordination seems to have value for this purpose in combination with the dominance distribution according to site fertility and moisture regime (Appendix V and VI) and to some characteristics species such as Cs, SPH and CLA. In Figure 6, many species lack significant correlation coefficients with moisture regime. This is explained by the fact that these species have a maximum dominance at moisture regime 2, 3 and 4 or have two maxima, one at moisture regime 0 and 1 and another at moisture regime 7, 8 and 9. These cases represent a curvilinear relationship which can be partly corrected by replacing the moisture regime by *Sphagnum spp.* as is seen in Figure 7. Now there is additional and complementary information which results from three ordinations of Figures 6, 7 and 8. Four principal groupings are distinguished from these graphs:

The first grouping is composed of species with a high dominance on fresh (mesic) sites where the black spruce associations with "mosses and herbs" or "mosses alone" of fertility class I and II are located. These species are:

Tree stratum	:	BEP, POt
Shrub stratum	:	DIl, SOa, ROa, VIp
Herb stratum	:	LIb, COc, MAc, ARn, TRb
Moss stratum	:	Cs, Hc, Du (HYp).

As is seen by its correlation coefficient with site index, *Hylocomium proliferum* (HYp) seems to be an indicator of a lower fertility site (class III and IV).

The second grouping is composed of species with a high dominance on dry (xeric) sites where the black spruce associations with lichens and dwarf shrubs of fertility class IV and V are located. These species are:

Shrub stratum : VA, KAa

Herb stratum : VAv

Moss stratum : CLA.

By their correlation coefficient with moisture regime and *Sphagnum spp.*, the Va, KAa and VAv have a high dominance on wet sites (See Appendix VI) but it appears by their greater correlation with CLA they are more closely related to dry sites.

The third grouping is composed of species with a high dominance on wet (hydric) sites where the black spruce associations with *Sphagnum spp.* and dwarf shrubs of fertility class IV and V are located. These species are:

Shrub stratum : LEg, KAp, CHAc

Herb stratum : VAo, CA, SMt, CHh

Moss stratum : SPH.

Species such as LEg, CA and CHh have a high dominance on dry sites but the importance of the dominance appears to be higher still on wet sites.

The fourth grouping can be considered as undefined preference species. The dominance of these species may be high on two extreme site moisture classes or may be characteristic of subhydric or subxeric sites together with black spruce associations of "mosses and dwarf shrubs". From these ordinations, it was impossible to further characterize them. The species of this grouping are:

Shrub stratum : VIc, ALr

Herb stratum : ASm, PEp, PTa, MIn, CLIb, COPg.

2-22 CONCLUSION.

Using some indicator species and site factors to define a coordinate system in which the species are ordinated according to their correlation coefficient with the axes defined, it appears possible to form species groupings having an ecological and phytosociological significance. Moreover, the position of the species in the ordinations can be explained provided the proper site factors and indicator species have been selected and the relationship between the graphs are understood. For black spruce stands, site index, moisture regime, cover of the tree stratum, and some basic species such as *Calliergon schreberi*, *Sphagnum spp.* and *Cladonia spp.* have given good results.

The dominance of certain species such as *Vaccinium spp.* and *Kalmia angustifolia* in particular, is markedly influenced by the cover of the tree stratum. Under this condition the estimation of site fertility by species composition or species dominance may give a wrong answer if the tree cover has been disturbed for one reason or another.

2-3 PRINCIPAL COMPONENT ANALYSIS.

2-31 METHOD.

It is necessary to mention only a few points on principal component analysis to situate and specify the techniques that have been used. The reader is referred to the different publications[23,40,79,87,88,89] mentioned in the bibliography to obtain more details.

The objective of the principal component method is to analyse the relation between "M" observed variables trying to explain these by a number of K independent variables named components and "M" independent variables named vectors. We have the following mathematical model with four observed variables: M = 4, K = 16.

Vectors		Y_1	Y_2	Y_3	Y_4
Variance		λ_1	λ_2	λ_3	λ_4
Components		A_{1_J}	A_{2_J}	A_{3_J}	A_{4_J}
Observed Variables	X_1	A_{11}	A_{12}	A_{13}	A_{14}
	X_2	A_{12}	A_{22}	A_{32}	A_{42}
	X_3	A_{13}	A_{23}	A_{33}	A_{43}
	X_4	A_{14}	A_{24}	A_{34}	A_{44}

Where vector $Y_1 = A_{11}\,X_1 + A_{12}\,X_2 + A_{13}\,X_3 + A_{14}\,X_4$ and the variance of Y_1 is $\lambda_1 = A_{11}{}^2 + A_{12}{}^2 + A_{13}{}^2 + A_{14}{}^2$.

The variance of Y_1 can be evaluated relative to the total variance of all the vectors: $\lambda_1\% = \dfrac{100\ \lambda_1}{(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4)}$

The λ % is the information given by the vector Y_1 and its components relative to the other vectors. The components and the square root of the variance of a given vector can be multiplied to obtain a loading component , so this permits the assignment of a relative importance to the component vectors according to their variance. The order of length of the vector will be proportionnal to the square root of the variance in such a way that variation of Y_1 will be higher than that of Y_2 and Y_2 higher than the variation of Y_3, etc.

Another way to treat the component matrix is to apply the "Varimax rotation". This method has been tried in this investigation but the results were no better than with the "loading components". (See Appendix XI).

Two particular variables are of interest in this model: The vectors and the components. The vectors are synthetic variables obtained from the observed variables and their components ($Y_1 = A_{11}X_1 + A_{12}X_2 + A_{13}X_3 \ldots$). If the observed variables are the species dominance, then each floristic list corresponding to the sample plots or forest types has vector values which can be used as ordinates in axes systems defined by the vectors. In this way it is possible to represent the forest types of plots in a vectorial ordination. Also, the components A_{1j}, A_{2j}, A_{3j} ... can be considered as the ordinate of the species in an area system where the species may be represented. The component ordination is a way to compare the species to see if there is a grouping of species which have similar characteristics.

There remains, yet, the choice of components and vectors to use as an ordinate. With an increase in the number of variables in the matrix the variance of the vector and the total variance will be higher. This occurs because the variance of the vector is equal to the addition of the square of the components of the observed variables ($\lambda_1 = A_{12}^2 + A_{12}^2 + A_{13}^2 \ldots$). The component corresponds to the variance of the variable for which it is responsible in the vector. The higher the component, the greater the observed variable is explanatory. This is not to say that a small component does not contribute significantly to a considered vector. For example, if a floristic list has only a few species, but a particular species is very important with regard to its dominance, then, it may have a small loading in the Y_1 and Y_2 vectors. This species would appear to contribute little by its component, relative to the other species, but becomes descriptive of a floristic unit and allows its location to be determined in vectorial space relative to any other units. For this particular reason it would appear that a species must be regarded not only according to its component in the vector but, also, according to its significance in the floristic community being studied. This observation is important because (1) in all statistical analyses by computer the number of permissible variables is limited and (2) the interpretation of the results is easier when the number of observed species is small. It is with this in mind that we have chosen the species in this report having the advantage of guidance by previous findings. (Linteau[74], Lafond[68]).

Generally the first three components and vectors accounted for 50 percent or more of the total variance. The information received was a large part of the information sought; particularly in the separation of the principal species groupings which characterize moisture regime and site fertility of the sample plots. In addition, in the analysis on the 28 species which were selected, the A_{4_j} component and Y_4 vector contributed additional information from the phytosociological view (Figure 11) and together with the other ordinations suggest a method of floristic classification.

Because of the computer capacity, only 28 species were used in the principal component analysis (See Appendix XI). The choice of the species was based on (1) their high correlation coefficients with site index and between themselves, and (2) their importance in the black spruce associations as observed in previous studies of Linteau[74] and Lafond[68]. Black spruce was not included in the analysis because its site fertility classification was the subject of the study and therefore was considered as a dependent variable. The species groups (X_1 --- X_6) were used in principal component analysis to study the effect of the grouping on the ordination of the species and site types and to see what value they may have for site fertility classification (See Appendix XII).

2-32 RESULTS AND DISCUSSION.

2-321 Component ordinations.

(a) According to the 28 species analysis the following species groupings listed by strata were observed: (See Figures 9, 10 and 11, and Appendix XI).

- Hydrophytic	grouping 1	(CHAc, LEg, KAp) (CHh, CA, SMt, VAo) (SPH)
- Mesophytic	grouping 2	(BEp, POt) (Cs, Hc)
	grouping 3	(SOa, DIl) (COc, LIb, MAc, TRb, ARn)
	grouping 4	(ASm, MIn, PEp)
	grouping 5	(HYp, Du)
- Xerophytic	grouping 6	(VA, Ka) (VAv) (CLA).

The species groupings defined by the component analysis were the same as those isolated by the correlation coefficients but showed better precision according to the moisture class. This result is logical since the component analysis was done on the matrix of interspecific relationships but considering it as a whole in such a way as to extract the maximum information of the different species.

Calliergon schreberi and *Hypnum crista-castrensis* constitute one distributional pole and *Sphagnum spp.* and *Cladonia spp.* constitute the other poles of the species in the ordination (Figures 9, 10, 11). This confirms what was found when considering only the correlation coefficients (Figures 5, 6). Moreover, a component analysis on the species divided by strata showed the same position of these species in ordination as was discussed above. This supports the theory that stable statistical information is available from these four species and for which the presence of other species does not affect the location in the ordination. Consequently, these four species could be the basic elements of some black spruce associations or ecologic units: The *Calliergon schreberi* and *Hypnum crista-castrensis* characterizing the mesophytic ecologic units where their dominance is optimum, the *Sphagnum* could be typical of the hydrophytic units and finally *Cladonia* could be the base element of xerophytic units. The other species would be attached to these basic elements depending on their dominance. But, everything is in a dynamic equilibrium such that there is a certain continuity in the dominance distribution of a species with an optimum for one given ecologic unit. Then, between these three poles the species distribution can be explained by their dominance behaviour in regard to these four species. Considering the third dimension $A3_j$ and by representing the species in the space difined by $A1_j$, $A2_j$ and $A3_j$ (Figures 9 and 10) we find that *Dicranum undulatum* (Du) is located between *Calliergon schreberi* (Cs) and *Cladonia* (CLA). This intermediate position results from the fact that Du is very often associated with CLA on the dry sites and with Cs on the fresh sites. *Hylocomium proliferum* (HYp), opposite to Du in the third dimension (Figure 10) and located near *Hypnum crista-castrensis* reflects the common occurance of these species in the *Hypnum - Hylocomium* association. The grouping (ASm, PEp, MIn) is located between Cs and SPH and which verified its association with Cs on the rich sites and with SPH on the poor sites such as the *Sphagnum-Petasites* site type. The species such as *Betula papyrifera, Populus tremuloides, Hypnum crista-castrensis, Sorbus americana, Cornus canadensis, Linnaea borealis, Maianthemum canadense, Trientalis borealis, Diervilla lonicera* and *Aralia nudicaulis* characterize to a greater extent, the fresh (mesic) sites but for which the dominance may be quite high on moist (subhydric) sites where their position between Cs and SPH is opposite to Du in the second dimension.

The results from the 28 species component analysis are, in general, in agreement with the species groups (Figure 12 and Appendix XII). Here also the moss and lichen groups define the poles from which the other groups are located.

Certain groups which are composed of species with a different ecological significance, tended to modify the relative position of other species. For example the presence of *Aster macrophyllus, Petasites palmatus* and *Mitella nuda* in group X_4 modifies the position of *Cornus canadensis, Linnaea borealis* and *Aralia nudicaulis* relative to *Calliergon schreberi*. We must not forget that these groups have been constituted for the purpose of a better characterization of the fertility class or to improve the dominance and fertility relationship. This objective was achieved since the grouping of species, with a low presence and dominance together with other species having a higher importance, tend to mask the first species and modify its position in component space. A typical example is the (SPH, CLA, HYp) group. If *Hylocomium proliferum* (HYp) were grouped with *Calliergon schreberi, Hypnum crista-castrensis* and *Dicranum undulatum*, the *Hypnum-Hylocomium* site type would be located in the same portion of the vectorial ordination as the *Calliergon* and the *Calliergon-Vaccinium* type which has been observed to have a higher fertility than the *Hypnum-Hylocomium* type. By this grouping we attribute a negative sign to HYp and this displaces the *Hypnum-Hylocomium* type in the vectorial ordination bringing a better order in the fertility classification. The reader will see further that this method also permits the differentiation of the site types used.

The variances of component analysis of the species groups were generally less than those of the analysis on 28 species for the respective vectors or for the total. But the components of the groups (observed variables) are, on the average, higher than of the species alone.

The percent variance of the components $A1_j$ and $A2_j$ accounts for a larger part of the total variance. In these components the information contributed by the species group is greater and is easier to explain inside a vector or in an ordination. The percent of variance better indicates the amount of a vector's information, within a certain limit, than does variance alone. The group has the effect of concentrating the species information under only one component. This reduces the number of components per unit vector, permitting the accumulation of greater variance for the first two or three vectors and gives a different significance and importance to certain species of the group.

2-322 Vectorial ordinations.

The results obtained may be studied in two ways: (1) Not knowing the phytosociologic units sampled an attempt may be made to group similar floristic lists trying to define the associations of groupings. (2) If the phytosociologic units are known and defined as, for example, the principle site types of Linteau[74], Lafond[68] and Damman[24], then these may be situated relative to the associations and sub-associations. In this last case each floristic list may be identified and an attempt made to determine, graphically, the area occupied by an association or sub-association or by a given site type. In this study, because of an insufficient number of sample plots for the large territory studied, the second method above appears to be better than the first assuming that a true identification of the site types has been made.

The reader must take into consideration the following points in the interpretation of the results: (1) The sampling has been done over a 5 year period. This introduces a possible error associated with the length of the study period since the dominance estimation from one year to another may vary somewhat. However, this error is, in part, self correcting in the case of the vectorial functions and the multiple regressions by its random presence in each of the observed variables of the same sample plots. (2) The site types have been identified to the best of our knowledge and experience. But this is relative, and if we use the same basic criteria for identification, there is the probability that similar site types will be given the same name and be near one another in vectorial space.

The site type ordination from the Y_1, Y_2, Y_3 and Y_4 vectors according to the component analysis on the 28 species are shown in Figures 13, 14 and 15. From these ordinations using the associations as defined by Linteau[74], and Lafond[68], it was possible to group the different site types under the following communities:

Association		Site type
1. Black spruce and balsam fir:		
a) with moss	:	H-HY

II. Black spruce alone :

a) with herbs + *Hypnum* moss: C-Co, C-PE

b) with *Hypnum* moss : C, C-VA

c) with moss dwarf shrubs: KA-C, LE-C, KA-LE, C-SPH

d) with *Sphagnum* dwarf shrubs: SPH-LE, LE-RU, LE-CHA, SPH-AL

e) with *Sphagnum* herbs : SPH-CA, SPH-PE

f) with *Cladonia* dwarf shrubs: KA-VA, CLA-VA, CLA-LE, CLA-Ka CLA-EM.

The Y_1 and Y_2 vectors of Figure 13 separate the black spruce associations very well with: *Hypnum* and herbs in the "A" area, moss and dwarf shrubs in the "C" area, *Cladonia* and dwarf shrubs in the "D" area and finally *Sphagnum* and dwarf shrubs in the "E" area. In the "B" area there are two associations, which do not differentiate themselves. They are black spruce with mosses and black spruce with *Hypnum* alone. But these two are isolated in the Y_1 versus Y_3 ordination (Figure 4), where the site types of these associations occupy some distinguishable area such as the *Calliergon* and *Calliergon-Vaccinium* in B and C areas respectively, while *Hypnum-Hylocomium* type is in the D area.

The Y_1 versus Y_4 ordination (Figure 15) gives the same information as Y_1 versus Y_2 but the black spruce association with *Sphagnum* and herbs identified by SPH-CA and SPH-PE seems to allow a better differentiation than in the other ordination.

These three ordinations allow the differentiation of some black spruce associations or communities only by the floristic factors but it is probable that the addition of site characteristics would bring even better precision. We see that it is better to use a combination of ordination

(Y_1, Y_2, $Y_1 \times Y_3$, $Y_1 \times Y_4$) to get the best separation of both the associations and the site types.

From the practical standpoint, vectorial ordination could be a very valuable instrument or technique for ecologic or phytosociologic classsification of the forest. If for a given region a complete vectorial ordination of the existing associations or ecologic groups is made by a specialist, it would be easier for a technician to use this kind of graph for classification. Knowing which site and floristic factors to measure, and by computing the ordinates (Y_1, Y_2, Y_3) of each plot with the vectorial functions, a technician could establish in which floristic association area of the graph his plot is located and therefore would be able to assign the correct name. Similarly, vectorial ordination may be used for site fertility classification. This point will be discussed in Part 3.

The site type ordinations according to the six species groups (X_1, X_2, X_3, X_4, X_5 and X_6) are shown in Figure 16. Some other combinations of groups have been tested but without receiving additional information.

Because of the grouping of the species, the black spruce associations and site types are less well differentiated than with the individual species. However a certain tendency toward differentiation can be detected.

The Y_1 and Y_3 ordinations have been tried according to the loading factors, but nothing more was gained than with Y_1 and Y_2.

With regard to site fertility the lack of differentiation of certain associations reflects the observations in the field. For example : the *Sphagnum*-dwarf shrub and *Cladonia*-dwarf shrub associations have a similar fertility as is found generally in class IV. Then, the objective sought by the species groups is attained by putting together, in the same area of the graph, the associations or site types having a similar class fertility, and thereby minimizing the work level of statistical analysis and sampling because of a fewer number of variables to measure.

The number of sample plots is not sufficient to allow a better vectorial distribution of the associations. Some trials have been done with the percent of covering of the species groups obtained by the quadrat method. It was found that the distribution of the association and site types of black spruce was somewhat better than with the graphs constructed by using the dominance of the groups. However, the additional work needed in the field does not seem to be justified. But, from that result it would appear that a more refined scale of dominance, particularly in the low class (0, 1 and 2) and especially for groups X_1, X_3 and X_4, would be more precise.

From the same component analysis a close relationship was observed between the ordination of the species or groups of species in the component ordination and the location of the associations or site types in the vectorial ordination. It would appear possible, by the component ordination, to predict and explain the distribution of the floristic communities in the vectorial ordinations and, indirectly, to predict the distribution of the fertility classes. In this regard it is possible to identify and take away the species or groups of species which decrease the clarity of the fertility class distributions.

2-33 CONCLUSION.

A close relationship was found between the correlation coefficient ordinations and the component ordinations. But the latter appear to be more precise in the distinction of the species grouping, than the former.

Moreover, it seems possible to explain the relative location of the species in the ordination by its dominance importance in the black spruce site types or associations. The moss species *Calliergon schreberi*, *Hypnum crista-castrensis*, *Sphagnum spp.*, *Cladonia spp.* bring stable statistical information and may be considered as distributional poles for other species.

The species groups modified the relative position of the individual species and, as a result, may contribute to a different distribution of the site types in vectorial ordination which may be more convenient to site fertility classification.

PART 3

UTILIZATION OF PRINCIPAL COMPONENT AND MULTIPLE REGRESSION ANALYSIS OF FLORISTIC FACTORS TO DETERMINE SITE FERTILITY

3-1 CLASSIFICATION OF SITE FERTILITY BY PRINCIPAL COMPONENT ANALYSIS.

Vectorial ordination appears to be a possible way of classifying the black spruce associations and also the site types. If there is a relationship between site fertility and the floristic or ecologic units then it is possible to use vectorial ordination for site fertility estimation.

In Part I a notable difference was shown in the fertility of the Continental and Atlantic regions. This means that the same phytosociologic group in these two regions may correspond to a different level of black spruce fertility on an absolute scale, but comparable in a relative scale within the same region. Such being the case, in this section the Continental region alone will be considered in order to work with a homogeneous population. In the presentation which follows, maximum statistical precision with a minimum of observed variables will be sought. In this regard the component analysis on correlation coefficients between species was not as good as those between species groups. Many trials were made with various numbers of species and the results show a fertility gradient in the ordinations but not as clearly as the trials with species groups.

The fertility classes are represented in the following manner in the ordinations (Figures 17, 18 and 19):

Fertility class	Site index class in feet	Class symbol
I	45 - 54.9	○
II	35 - 44.9	●
III	25 - 34.9	★
IV	15 - 24.9	□
V	2.5 - 14.9	▲

3-11 RESULTS AND DISCUSSION.

Figures 17 and 18 show the fertility class distribution of the Continental region. The fertility gradient from the upper part to the lower part of the graph is very noticeable but a sector type distribution is indicated. The sector of each fertility class has been delineated by joining the outermost data with straight lines.

Unfortunately there were only 50 sample plots for the Continental region in the case of species groups. Figure 17 shows the fertility class distribution according to all of the 6 available species groups and Figure 18 shows the 5 principal groups with regard to the black spruce associations.

The results obtained are of value particularly if we take into account the vector Y_3, that is, the third dimension. With modest effort, the reader may see the fertility class distribution in three dimensions where the concentric nature of the surfaces or the spaces occupied by the different classes may be noted. Due to the limited number of sample plots (50), it is impossible to arrive at a final conclusion regarding site index. However, it appears that the component analysis of "species groups" promises more precise results in the segregation of fertility classes than has been reported elsewhere, particularly if certain site factors are added to the analysis.

An additional trial with 4 species groups (X_1, X_2, X_4 and X_6), which comprised 26 species, was completed with encouraging results. If the number of species appears to be high, it must not be forgotten that for a trained technician the dominance estimation for one group is made very rapidly, since, the species composing each group belong generally to the same stratum (except for group X_1). This estimation is particularly easy in certain strata where the sociologic structure of plant communities is made up of tufts, or colonies, and the species of the same group occupy a given area near one another.

The X_1 is of interest in bringing together certain tree species like *Betula papyrifera*, *Populus tremuloides*, *Populus balsamifera*, and *Betula lutea* and perhaps certain small tree species such as *Prunus pensylvanica*, *Acer spicatum* and *Acer pensylvanicum* depending of the region studied. For certain groups such as X_1, X_3 and X_4 for which the dominance range was low (from 0 to 3 generally), there may be advantages to refining the scale of dominance especially in the lesser classes of cover (0 to 5%, 5 to 20%).

The trials with "varimax" vectors did not bring about any important improvement of the fertility class distribution, but only resulted in clearer separation of the classes especially with vector Y_3. This may become very valuable in practice because rather than work in three dimensions we might, by the combination of the two planes Y_1 versus Y_2 and Y_2 versus Y_3, classify the sample plots, when the area occupied by the fertility class has been well determined.

Figure 19 presents the fertility class distribution of the Atlantic region compared to the Continental region, as obtained from the component analysis of the dominance relationship between the 28 species on the total region. The restricted number of sample plots (25) of the Atlantic region precludes any definative component analysis. We can observe, however, a displacement of the fertility class in Figure 19 and this was the same with the species groups. Therefore there is the possibility of using the interspecific relationships of the dominance for the total region to classify site fertility. However, it would appear that the ordination should be done only with a region or area in which a homogeneous population (according to the relation of floristic dominance versus site index) is present. These last relationships must have similar correlation coefficients with the dominance of the species studied but may be at a different level of general fertility for some given regions.

3-12 CONCLUSION.

With component analysis it seems possible to construct some graphical identification keys of the site types or other phyto-ecologic units. It is also possible to construct fertility key in these same units. One advantage to this is the use of the same data to establish the two kinds of keys. These keys would allow a rapid and easy classification of plots or sites by technical personnel using vectorial functions to calculate the coordinates of the given units and thereby locate their position in the graphs.

Species groups appear to be efficient for fertility classification in vectorial ordination. A more precise dominance scale, particularly in the lower class, will probably improve the ordination. The addition of site factors, the closer study of the information contributed by the species according to site fertility and the regional application of the ordination will certainly give rise to a more precise distribution of the fertility classes.

3-2 UTILIZATION OF MULTIPLE REGRESSION TO EVALUATE SITE WITH THE FLORISTIC FACTORS.

Multiple regressions are a practical and easy way to use vegetational factors for fertility prediction. However, they are sometimes difficult to interpret and have restricted application in the biologic sciences. This is because the observed variables are frequently inter-dependent and therefore highly correlated among themselves.

The method used here is that of step-wise multiple regression, using linear and curvilinear relationships. As this technique of analysis is well known, it is not necessary to explain it here but only to emphasize the details as they apply to this study. The basic steps of these analyses are as follows:

1-. Because of the difference in fertility between the Continental and Atlantic regions, the regional regressions were computed separately.

2-. With the species alone and with the species groups having an estimated dominance, a search was made for the best multiple regression equation for site index prediction.

3-. The Continental region, from the floristic inventory, comprised two geologic-climatic areas: (a) Granitic soils and (b) Clay soils. A check was made as to the possible improvement in the precision of the multiple regression relationship established with the species groups, for each of these soil areas as well as for the Atlantic region.

4-. Finally, by the soil classification based on the mechanical analysis of the plots and by the plot moisture regime, a residual error analysis was made (observed site index minus computed site index) to check the influence of these two site factors on the regression precision. No relationship was evident.

3-21 RESULTS AND DISCUSSION.

In the study of the results we must take into consideration the following points: (1) within a sample plot, measuring the height of 5 dominant and 5 codominant black spruce to ±1 foot and taking the respective stump age, the mean site index at 50 years may be estimated to ±1 foot of standard error and with a plot standard deviation of ±4 feet. Therefore, we cannot expect greater precision than this in using floristic factors to predict site index. (2) The multiple regressions of the geologic-climatic region have only a limited predictive value because of the restricted number of observations. For these same reasons we have not used the curvilinear relationship in the case of the Atlantic region. Only the selected variables over all the Continental regions have been used in multiple regression analysis of respective geologic-climatic regions.

3-211 Results from species (Continental region).

(1) $S.I. = 38.72 + 3.37\ BEp - 2.47\ CHAc - 0.73\ LEg - 2.94\ HYp - 1.84\ SPH - 3.30\ CLA + 1.75\ COc + 5.47\ TRb.$

n	:	Number of observations: 100
s	:	Standard deviation of S.I. : ±11.43 feet
sy.x	:	Sample standard deviation about regression in feet: ±6.63 feet
R^2	:	Coefficient of determination: 0.69
F of TRb	:	The F value of the last variable introduced in the regression 8.92 (significant at 99 percent).

3-212 Results from species groups (see section 0-443)

(a) Continental region.

n = 50, s = 10.1 feet

(2) $S.I. = 35.40 + 6.23\ X_1 - 2.80\ X_6$

sy.x = ± 5.63 ft., $R^2 = 0.70$, F of $X_6 = 18.96$

(3) $S.I. = 32.56 + 5.54\ X_1 - 2.43\ X_6 + 2.00\ X_4$

sy.x = ±5.42 ft., $R^2 = 0.73$, F of $X_4 = 4.77$

(4) $S.I. = 29.50 + 5.63\ X_1 - 2.13\ X_6 + 5.34\ X_4 - 0.81\ X_4^2$

sy.x = ±5.33 ft., $R^2 = 0.74$, F of $X_4^2 = 2.69$ (non significant)

(5) $S.I. = 37.00 + 5.12\ X_1 - 3.01\ X_6 + 5.34\ X_4 - 0.81\ X_4^2 - 1.05\ X_5$

sy.x = 5.28 ft., $R^2 = 0.75$, F of $X_5 = 1.69$ (non significant).

(b) Continental granitic soils region.

n = 25, s = ±9.62 feet

(6) $S.I. = 31.55 + 7.53\ X_1 - 1.76\ X_6$

sy.x = ±4.47 ft., $R^2 = 0.80$, F of $X_6 = 6.20$

(c) Continental clay soil region.

$n = 25 \quad s = \pm 10.75$ feet

(7) $S.I. = 33.80 + 4.85\ X_1 - 3.48\ X_6 + 3.72\ X_4$

$sy.x = \pm 5.97$ ft., $R^2 = 0.73$, F of $X_4 = 5.63$

(d) Atlantic granitic soils region.

$n = 25, \quad s = \pm 10.59$ feet

(8) $S.I. = 29.21 + 5.97\ X_1 - 7.48\ X_3 - 2.63\ X_2$

$sy.x = \pm 6.90$ ft., $R^2 = 0.63$, F of $X_2 = 7.65$

The multiple regressions established with the species groups are clearly superior to those with the species taken individually. This is explained by the following observations: (a) The groups indicate a certain continuity in the relation site index *versus* the dominance of the species which compose it and the correlation coefficients of the groups are somewhat higher than those of the species used. The groups include the species having a similar relationship with site index and may have either an identical or different ecology. In this way the groups take into account many sites and also the competition between species of the same ecology, reducing, at the same time, the number of variables in the regression. (b) The estimation of the group dominance is more precise because the species forming it belong generally to the same stratum and the sociability of them in the black spruce domaine is frequently by tufts or colonies. Thus, the estimation error is relatively small since the estimate is made collectively and the numerical value of the cover percent is large.

It should be noted that BEp, CHAc, LEg, SPH, HYp, and COc are included in groups X_1, X_2, X_6 and X_4 and these species and groups were selected independently by the computer because of their high association with S.I. and were therefore used to compute the best multiple regressions.

It is probable that with groups X_1, X_3 and X_4 an improved precision could have been obtained if a refined dominance scale had been used for the low classes of the scale. These groups generally had a small variation in dominance (0 to 3) throughout the study area.

Group X_3 seems to have had particular importance within the Atlantic region. It should be noted that this group is far from being perfect in species composition. *Clintonia borealis* (CLIb) and *Equisetum spp.* (EQ) in our opinion must be excluded from this group and replaced by *Epigaea repens* (EPGr) and *Gaultheria procumbens* (GAp).

In the final report of this series it is hoped that the inclusion of other site factors to the multiple regression will improve the precision of estimating site index. For this reason, equations 4 and 5 have been retained for possible use in later studies.

From the favourable results obtained by geologic-climatic regions it is expected that the multiple regressions here included might be markedly improved upon application to smaller areas.

With Figure 20 and as indicated by the R^2 of the regressions with groups approximately 75 percent of the plots are within one standard error and 96 percent within 2 standard errors of the predicted value for site index.

The standard errors of the regressions (2) and (5) vary between 5.3 and 5.6 feet which corresponds to a little more than one-half of the interval of a fertility class. For this reason it is reasonably certain that a particular estimate will fall within the correct fertility class.

A comparison of site index prediction obtained from Linteau's site type and from multiple regression number 3 is shown in Table 5. Because the site type description of Linteau was done over the region of Section B-1 of Rowe[85] the mean deviation and bias with regard to that region and for all the Continental region was computed. Only the site types described by Linteau were included in the comparison. It would appear that no significant bias in the average site index occured by either method of comparison. This would indicate that the site types of Linteau[74] are applicable outside of Section B-1. However, the average deviation both within and outside Section B-1 were smaller for the multiple regression method than for Linteau's site types. This increased precision undoubtedly occurs because site type transitions can be identified by multiple regression and not by Linteau's classification. Also, this precision of multiple regression would be expected to be even better if the prediction equation were more restricted as to a particular region.

3-22 CONCLUSION.

The multiple regression equations with the vegetative factors appear to be useful for site index prediction and site fertility classification. The species groups appear to be more precise than the individual species. In addition a more refined dominance scale in the lower classes, modification of the species composition of the groups as proposed in the discussion and the use of regional studies will certainly improve prediction precision. Moreover, the use of certain site factors may be of benefit.

It would appear that the site types of Linteau are applicable to a large part of the eastern Boreal Forest. However, the multiple regression appears to be more precise for site index prediction than the site types.

Table 5. Comparisons of observed site index with the predicted site index by Linteau's site types and by multiple regression.

Plot No.	Observed S.I.	Site type Linteau	Predicted S.I. of Linteau Ft.	D from Linteau obs-pred Ft.	Predicted S.I. Multiple regression Ft.	D from regression obs-pred Ft.
Continental Region, Section B-1 of Quebec						
113	31.5	C	37.1	- 5.6	37.7	- 6.2
114	39.3	C	37.1	2.2	37.7	1.6
115	40.1	C	37.1	3.0	37.7	2.4
116	19.9	CLA-LE	29.0	- 9.1	20.4	- 0.5
117	21.1	SPH-LE	19.4	1.7	18.0	3.1
118	46.0	C-CO	38.7	7.3	45.2	0.8
119	31.6	C	37.1	- 5.5	35.2	- 3.6
121	27.6	KA-VA	33.0	- 5.4	22.8	4.8
122	46.4	C-CO	38.7	7.7	45.2	1.2
Σ	303.5		307.2	47.5	299.9	24.2
Mean	33.7		34.1	5.3	33.3	2.7
Ave.Bias			+ 0.4		- 0.4	
Quebec other than Section B-1 and Ontario						
53	43.9	C-CO	38.7	5.2	51.2	- 7.3
54	42.0	C-VA	40.5	1.5	43.2	- 1.2
55	51.3	C-VA	40.5	10.8	43.2	8.1
56	34.3	SHP-LE	19.4	15.0	27.9	6.5
57	18.5	SPH-LE	19.4	- 0.9	20.0	- 1.4
109	36.2	C	37.1	- 0.9	37.7	- 1.5
111	33.2	C	37.1	- 3.9	37.7	- 4.5
123	33.4	C	37.1	- 3.7	37.7	- 4.3
124	26.6	C	37.1	-10.5	37.7	-11.1
126	19.2	CLA-VA	30.0	-10.8	20.4	- 1.2
127	41.5	C-CO	38.7	2.8	47.2	- 5.7
61	34.3	SPH-LE	19.4	14.9	22.4	11.9
91	43.4	C-CO	38.7	4.7	41.7	1.7
92	33.8	C-VA	40.5	- 6.7	34.1	- 0.3
93	42.0	C	37.1	4.9	37.7	4.3
94	41.3	C	37.1	4.2	37.7	3.6
98	40.3	C	37.1	3.2	35.2	5.1
99	46.3	C-CO	38.7	7.6	46.3	0
101	29.2	C	37.1	- 7.9	33.2	- 4.0
103	30.3	C	37.1	- 6.8	35.2	- 4.9
104	41.4	C	37.1	4.3	40.8	0.6
107	37.2	C	37.1	0.1	37.7	- 0.5
Acc.Σ	1103.2		1079.8	178.8	1105.8	113.9
Acc.Mean	35.6		34.8	5.8	35.7	3.7
Ave.Acc Bias			- 0.8		+ 0.1	

Multiple regression : $S.I. = 32.56 + 5.54\ X_1 + 2.43\ X_6 + 2.00\ X_4$

PART 4

GENERAL CONCLUSIONS

4-1 THE VASCULAR FLORA.

The observations from our method of sampling verify the conclusion of LaRoi[73] in that the diversity of the vascular species increases from east to west starting from the Maritime Provinces (Newfoundland) to reach a maximum north of the Great Lakes (Ontario). This variation seems to be related to the major soil formations, to the climatic conditions and also may depend to a certain degree on the geographical distribution of the species, which may be in extension or regression.

4-2 THE DOMINANCE.

As a measurement criterion, related to the species or species groups, the dominance appears to be very well adapted to the coniferous Boreal forest. The dominance of species and species groups is closely related to site fertility, and as a result allows the: (a) characterization of the fertility class by the species groups, (b) possible classification of the sample plots according to the fertility class by factorial analysis, and

(c) calculation of multiple regressions with the species groups determining the site indices with a precision varying from ±5.3 to ±5.6 feet, depending on the variables and region in question.

In addition, component analysis of the interspecific and inter-species groups dominance relationships has indicated that it is possible to classify black spruce sites into associations and perhaps into site types by the vectorial ordinations. It would seem that this is an adequate method of classification which is suitable for use by technicians who are not necessarily vegetation specialists.

Finally, the dominance scale would probably become better in the lower part of the scale if the estimate were more refined. This is particularly true for the species belonging to the herbaceous stratum and the hardwoods from the tree and shrub strata. This modification would increase the precision of interspecific and inter-group relationships, and consequently, would affect the precision of prediction of site index, as in the case of the distribution of fertility classes in vectorial ordination. Therefore, it should prove worthwhile in future studies to search for a method of weighting the dominance which would allow additional relative importance to be given to the species and groups inside an association.

4-3 THE SITE TYPES.

Across eastern Canada the same site type may represent different fertility levels. This may be explained if one considers the site type as the result of integrating many site factors. A site type results from the combination of these factors, but may be the result of many possible combinations. For example, the *Calliergon* type may be located on a fresh silty clay soil as well as on a less fertile fresh morainic soil, but sufficiently fertile to support a black spruce stand of good growth. The site index in these two cases will be different as in the case where a similar site type is found under two regional climates differing by the length of the growing period, in the amount of precipitation, or some other factor which is observable within the scale of eastern Canada.

To use the site types for classification of site, a growth study must first be done, at the regional level, to estimate the fertility of the types.

The continuity of the vegetation becomes a governing factor in classification because if for a given region an ecologic unit is very representative, for other regions it may be secondary or simply an intermediate unit. This is to say that if the vegetation of a territory may be subdivided into characteristic ecologic units, these units will not be, necessarily, representative elsewhere and consequently it would be better to establish the importance of a unit for a given region before making a classification. The selection of a region with a homogeneous geomorphology, topography and climate is a first condition to avoid all misunderstanding. That is to say that any ecologic unit is "characteristic" or "intermediate" depending on what it represents.

Component analysis seems to be a suitable way to define the ecologic or phytosociologic unit when there is a continuity to the linear vectorial functions. By these analyses it has been possible to locate, in vectorial ordination, positions of an association and site type relative to one another (Figures 13, 14, 15). This permits one to see the transition from one to another. By an adequate sampling in quantity and quality it is probable that a center, grouping many types, would be formed in vectorial ordination and that for a given region each grouping may represent an ecologic unit representative of the sampling area. When these principal units are well-defined, the only thing remaining is to group under them, the intermediate units, taking into account the similarities of ecology, productivity and silvicultural practices.

4-4 METHOD OF FERTILITY ESTIMATION.

Three methods are presented depending on the precision sought. They are: (a) site types; (b) the principal component analysis and (c) multiple regression.

(a) The site types as proposed by Linteau[74] appears to be applicable over a large part of the eastern Boreal forest. The prediction of site index by this method is less precise than by multiple regression with species groups.

(b) The component analysis shows a possible classification of sites according to fertility classes of 10 feet each. The data presented in this investigation are only exploratory and merit a more intensive study to define the distribution of the fertility classes. It would appear that a regional application, an improvement of the dominance scale and a study of the species and species groups closely related to fertility, would increase the analytical precision. It should be noted that the species groups have been found to be very valuable in this regard. At present there is no way to adequately judge the numerical precision of this method.

(c) The multiple regressions established using the species groups are the most precise and allow a prediction of site index for a single plot to ±5.5 feet, generally. In that way it is possible to identify the fertility class of a given site with reasonable probability, (the class interval (10 units) is equal to about twice the standard error, sy.x, (±5.5 feet). The previous remarks concerned with the component analysis apply to the multiple regressions, that is, there should be advantages to working on a regional basis. In addition, multiple regression analysis can be tailored to suit either aerial photo interpretation or ground observation. For example, with aerial photos taken at the time of leafing out, the hardwood species (X_1) would be clearly discernable. A modification of X_6 to exclude *Hylocomium proliferum* (HYp) would permit its use in a similar way since both *Sphagnum spp.* and *Cladonia spp.* can be seen from photos when not obscured by tree foliage or snow. With ground observations there are no serious restrictions on the species to be used provided there are not too many of them. With the use of a pocket guide or circular slide rule, rapid estimate of site fertility can be made in a matter of minutes. It is possible that the addition of other site factors would improve the precision of prediction.

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F I G U R E S

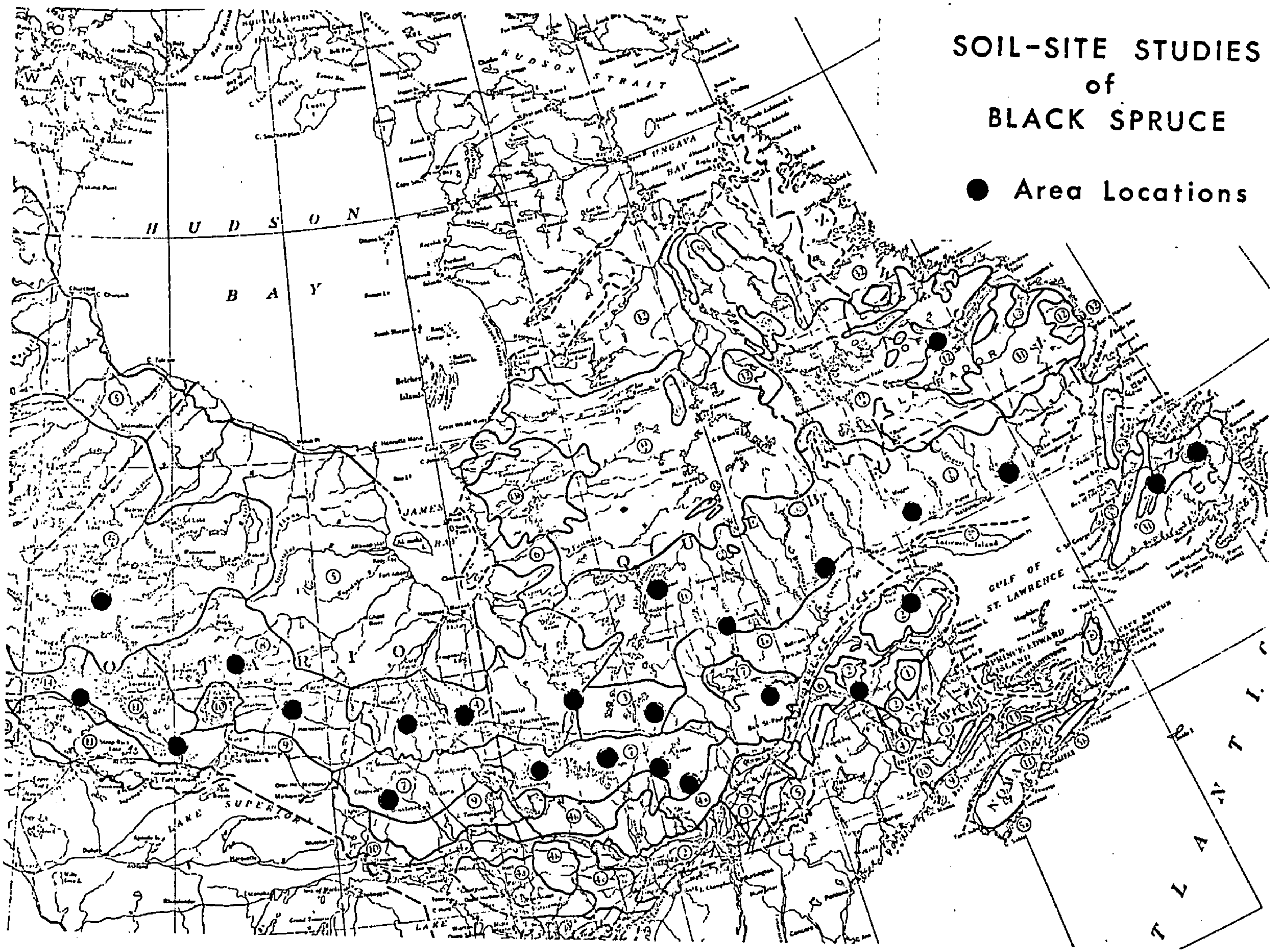

Figure 1. Study area locations.

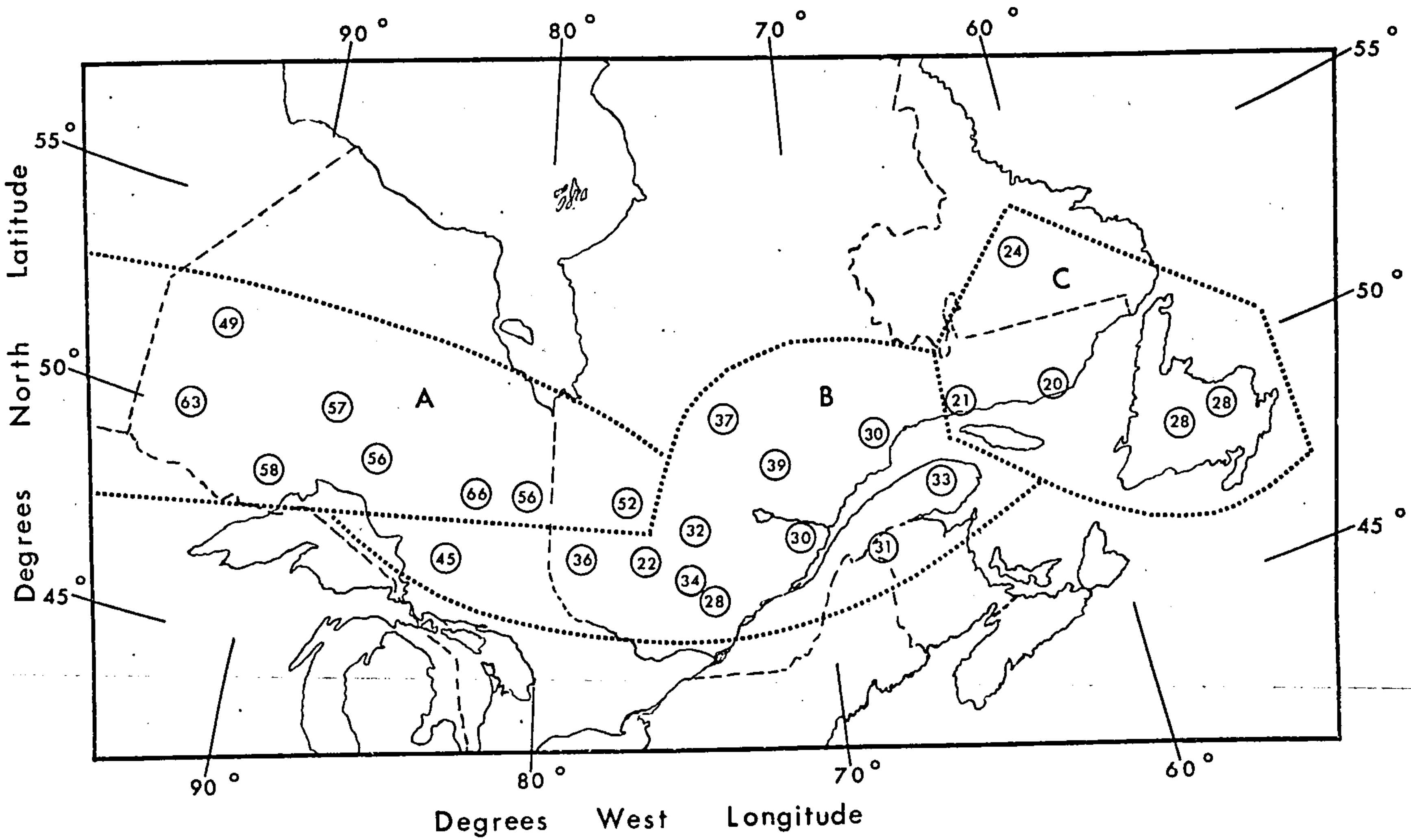

Figure 2. Geographical distribution of the total number of vascular species by location.

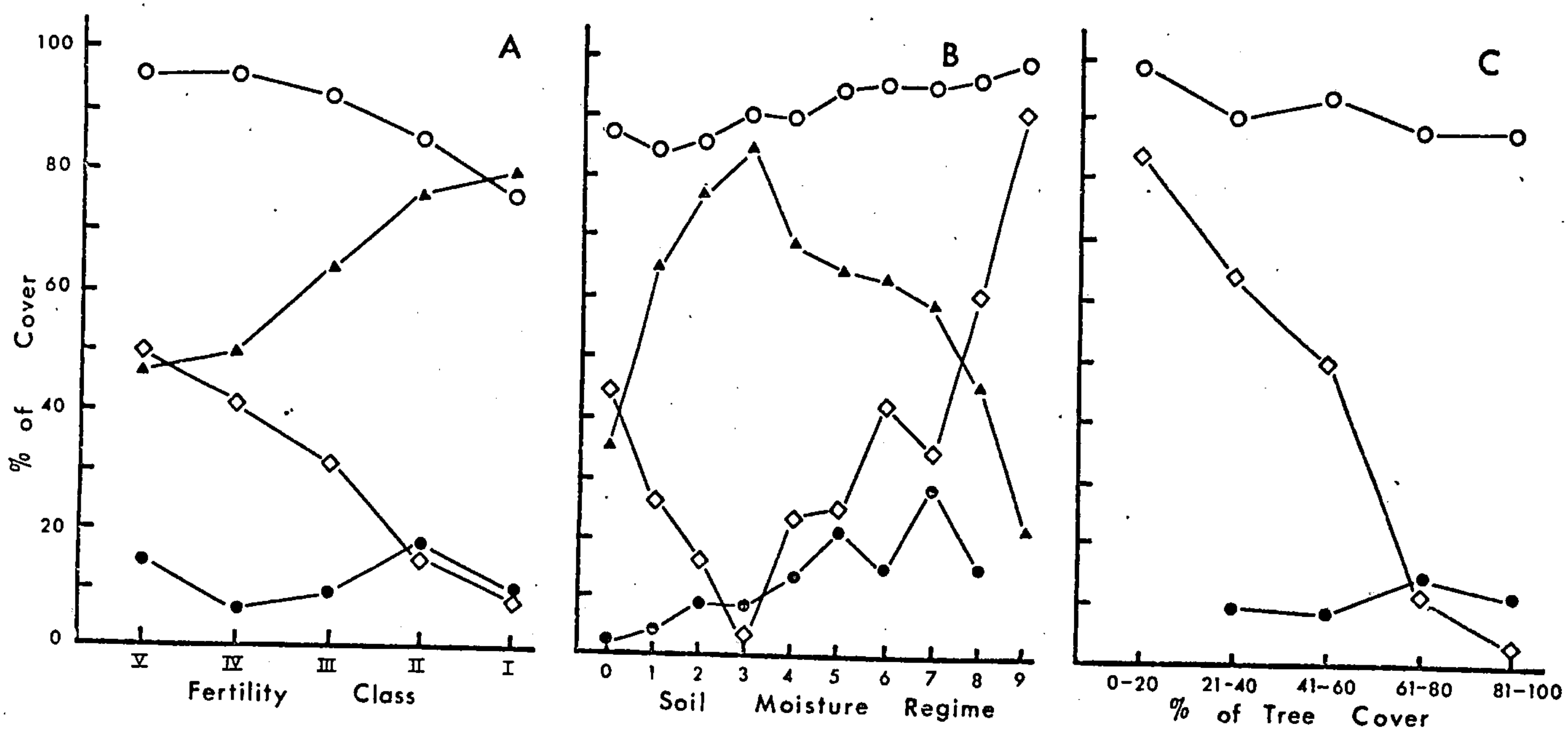

Figure 3. Distribution of mean percent of cover of the strata of Trees (▲), Shrubs (◇), Herbaceous (●) and Moss (○), for the total region.

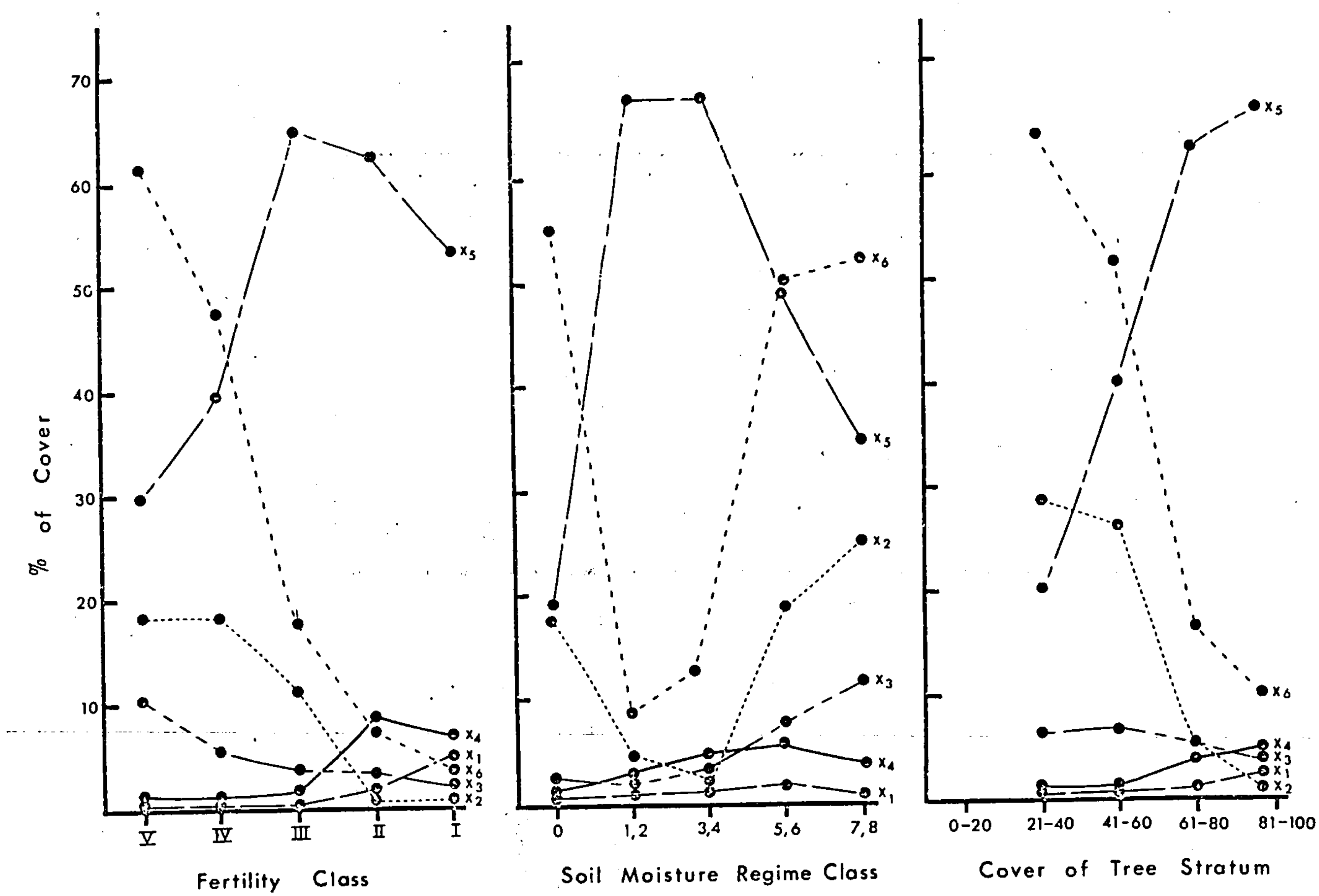

Figure 4. Distribution of the mean percent of cover of species groups with regard to the three ecologic facrors of fertility, moisture regime and tree density. (Percent of cover was directly estimated by the quadrat method).

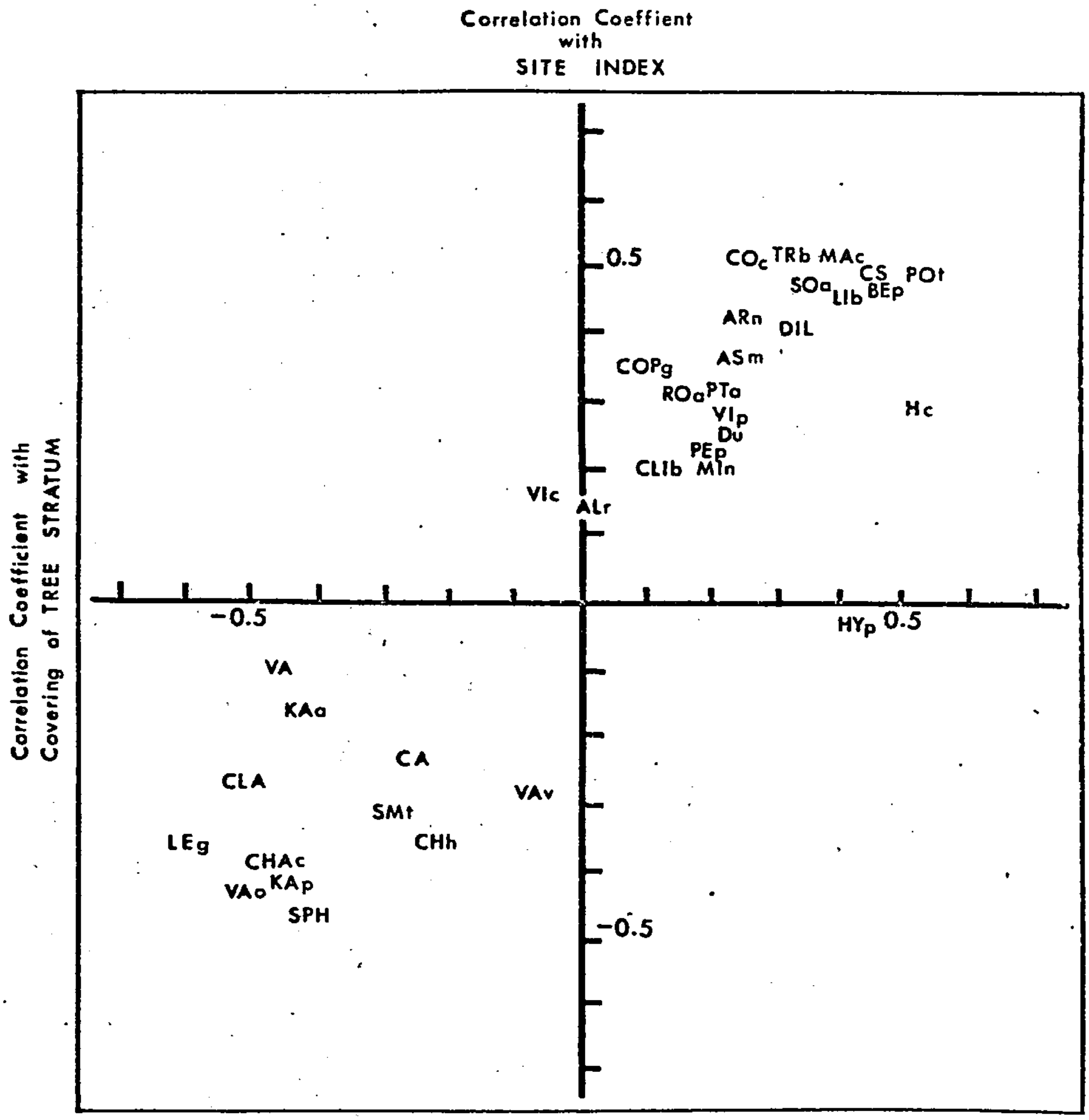

Figure 5. Ordination of the species with respect to their correlation coefficients between dominance and site index and between dominance and percent density of the tree stratum.

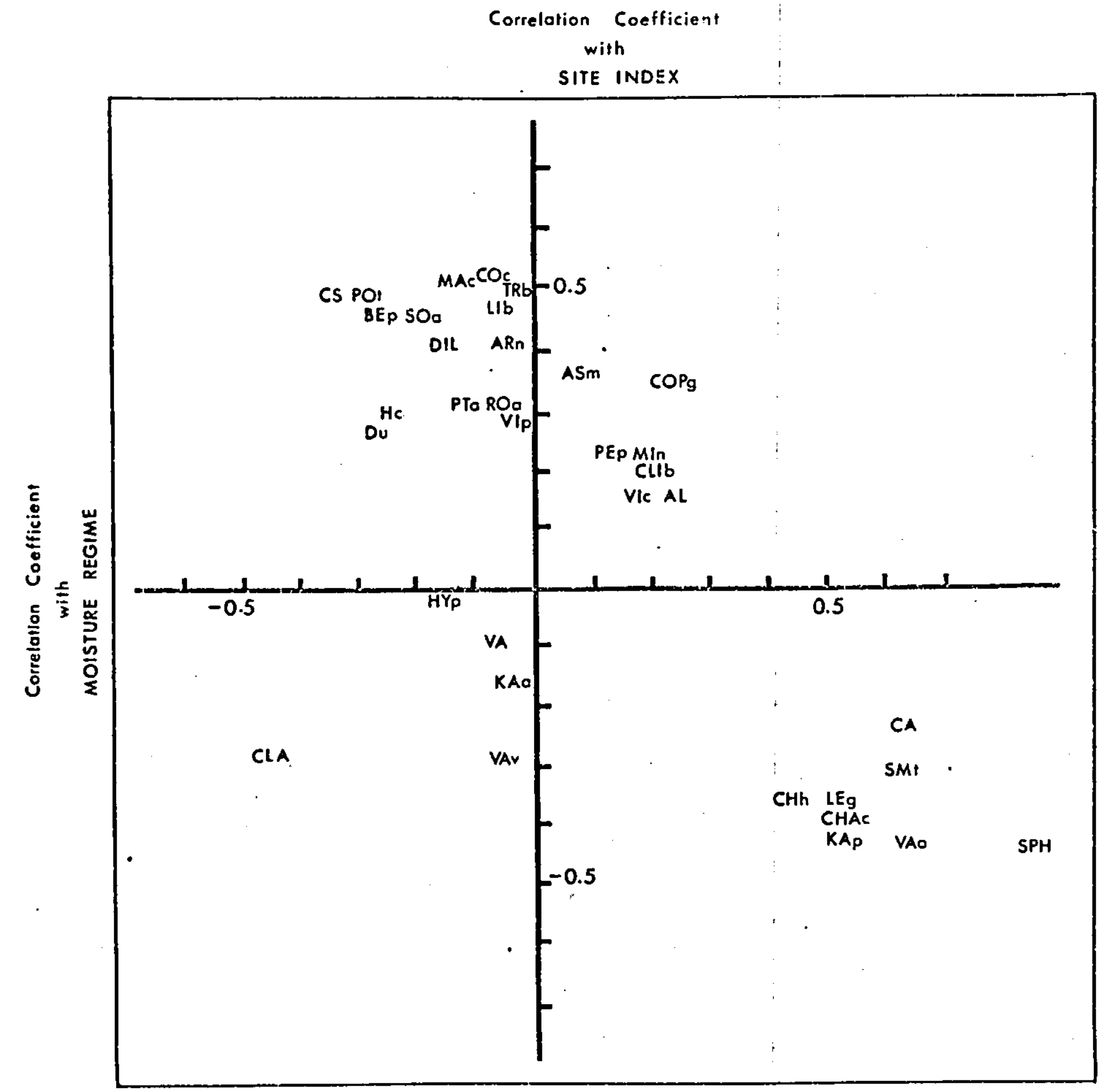

Figure 6. Ordination of the species with respect to their correlation coefficients between dominance and site index and between dominance and moisture regime.

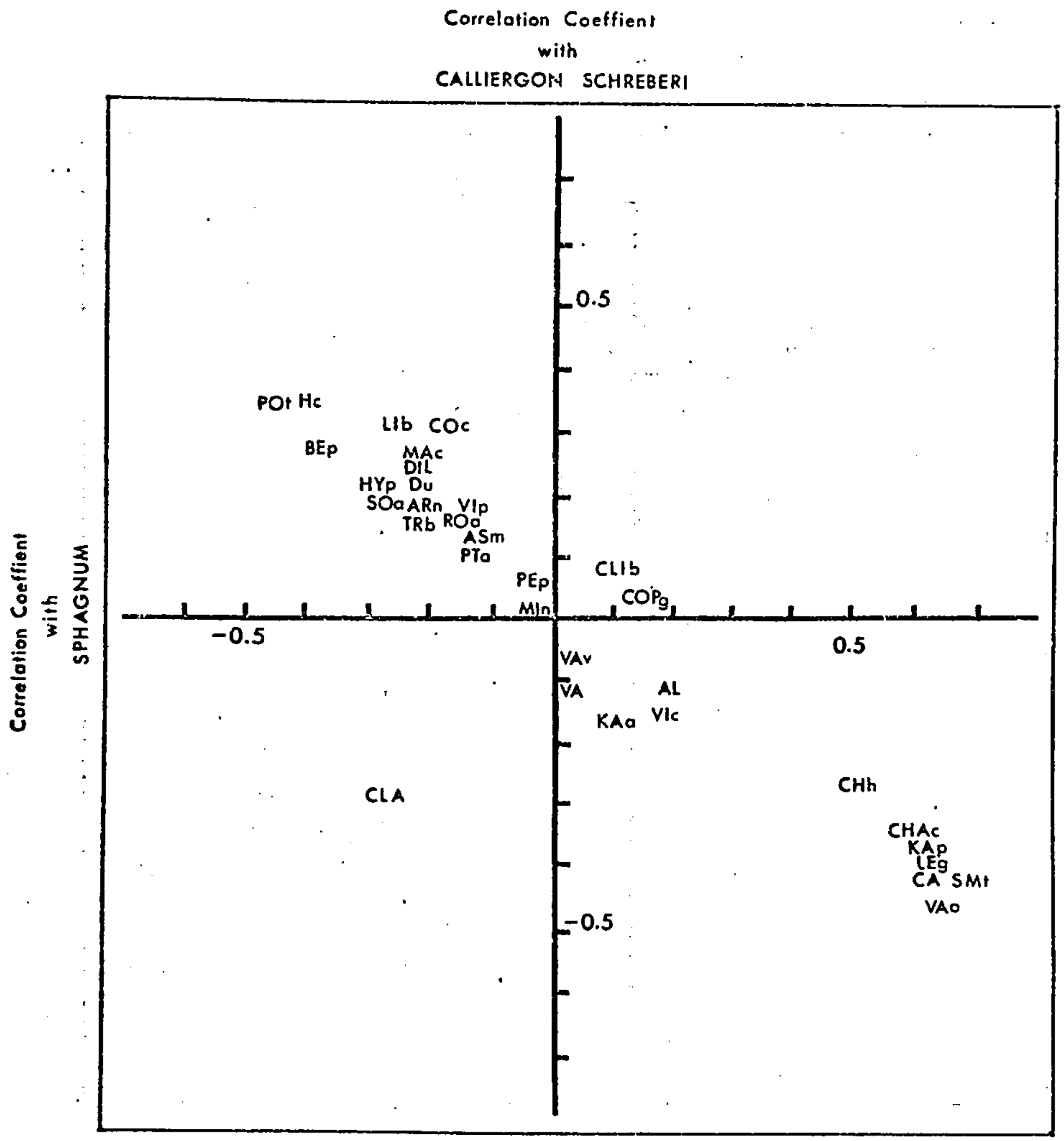

Figure 7. Ordination of species with respect to their correlation coefficients between dominance and that of *Calliergon schreberi* and between dominance and that of *Sphagnum spp.*

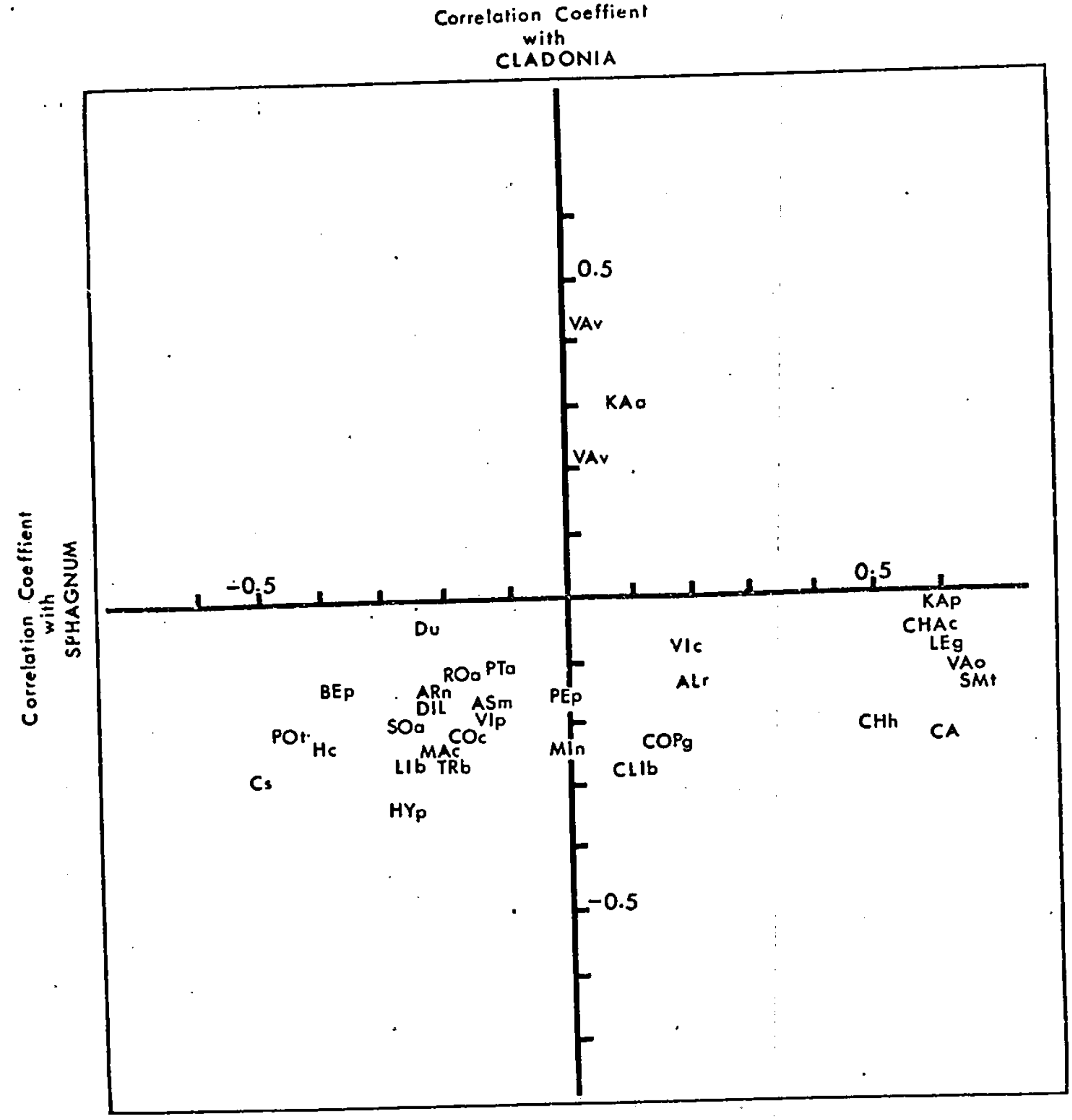

Figure 8. Ordination of species with respect to their correlation coefficients between dominance and that of *Cladonia spp.* and between dominance and that of *Sphagnum spp.*

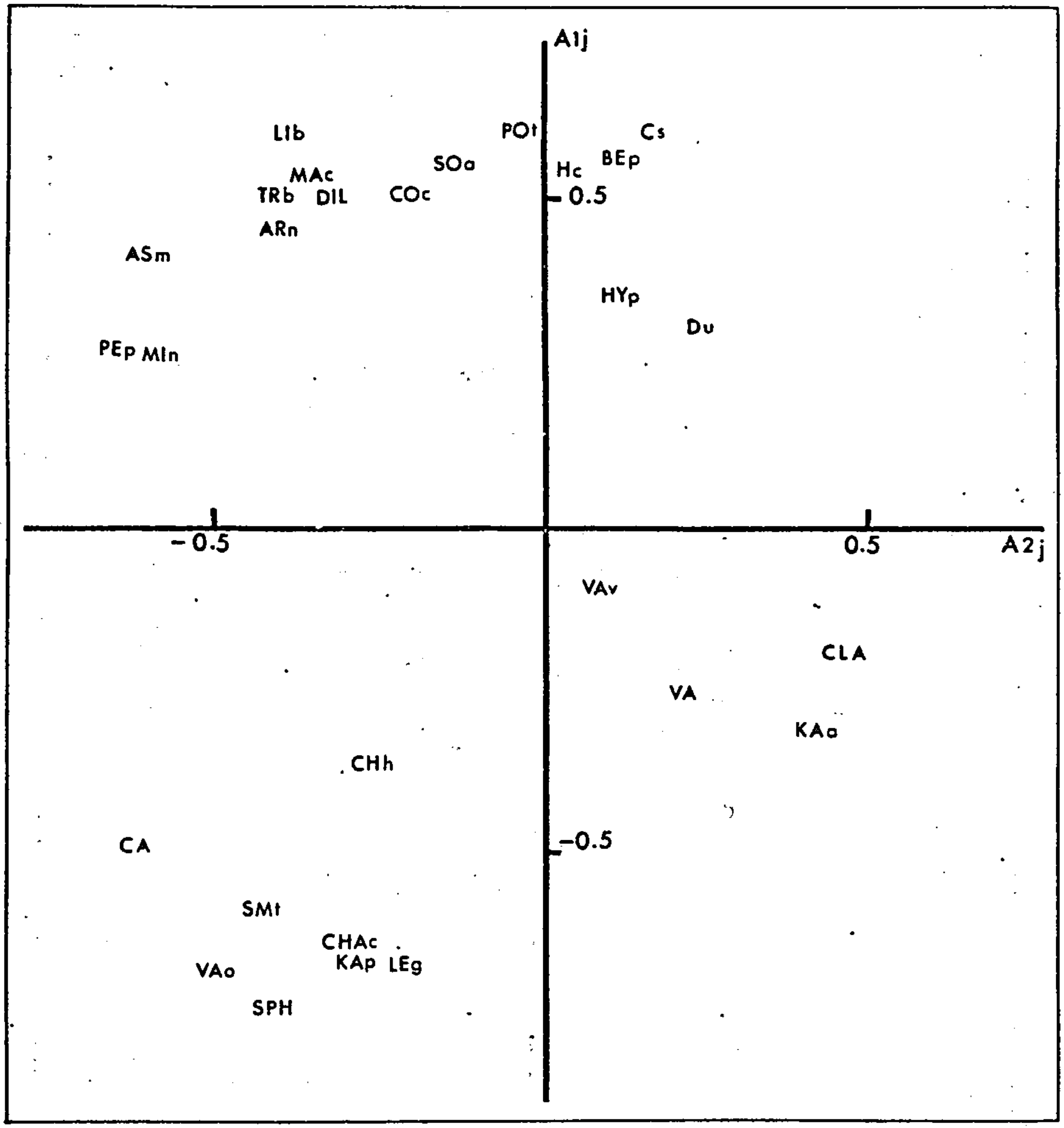

Figure 9. Ordination of 28 species common to black spruce stands, according to loading components A_{1j} and A_{2j}

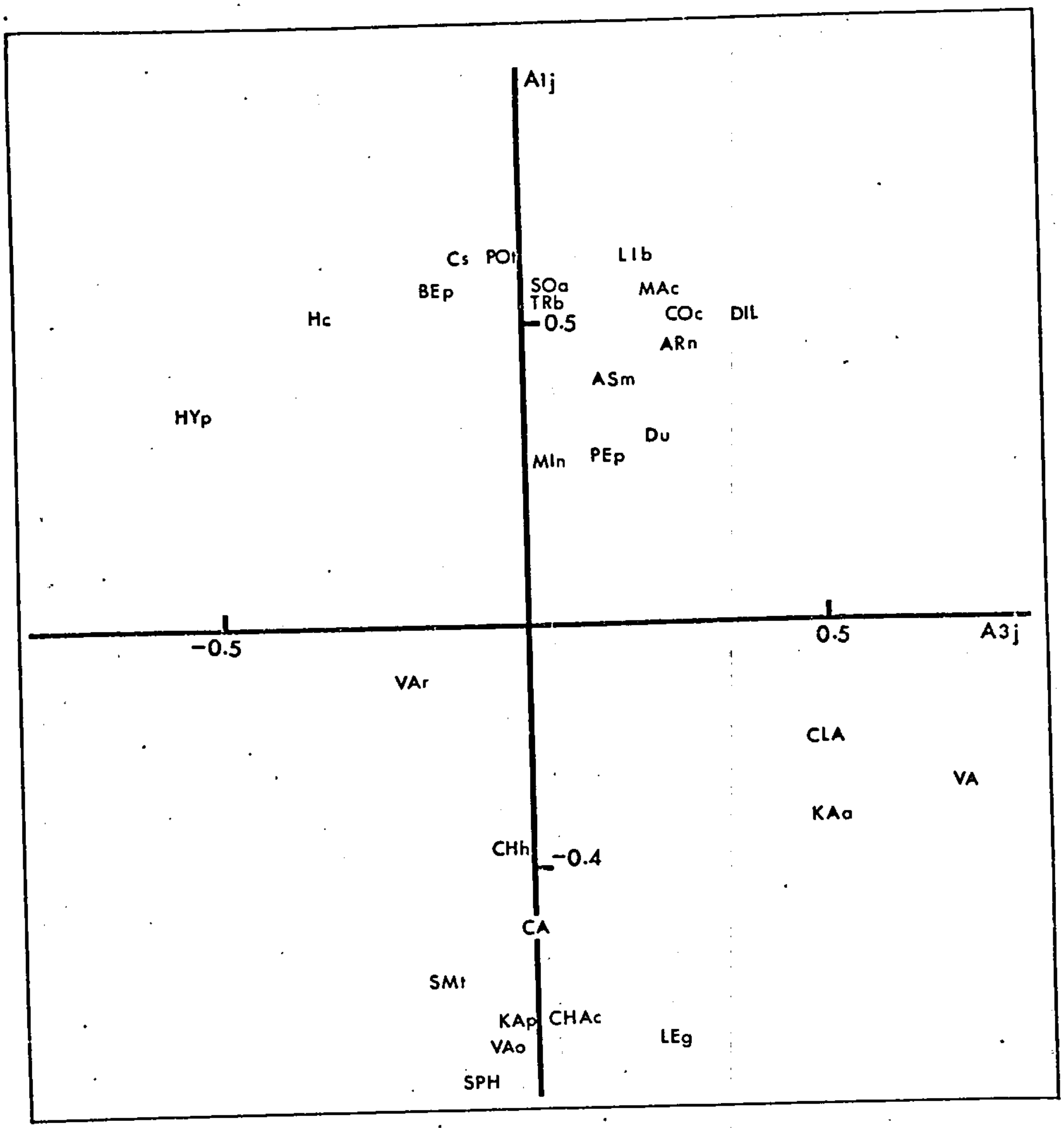

Figure 10. Ordination of 28 species common to black spruce stands according to loading components A_{1j}, and A_{3j}.

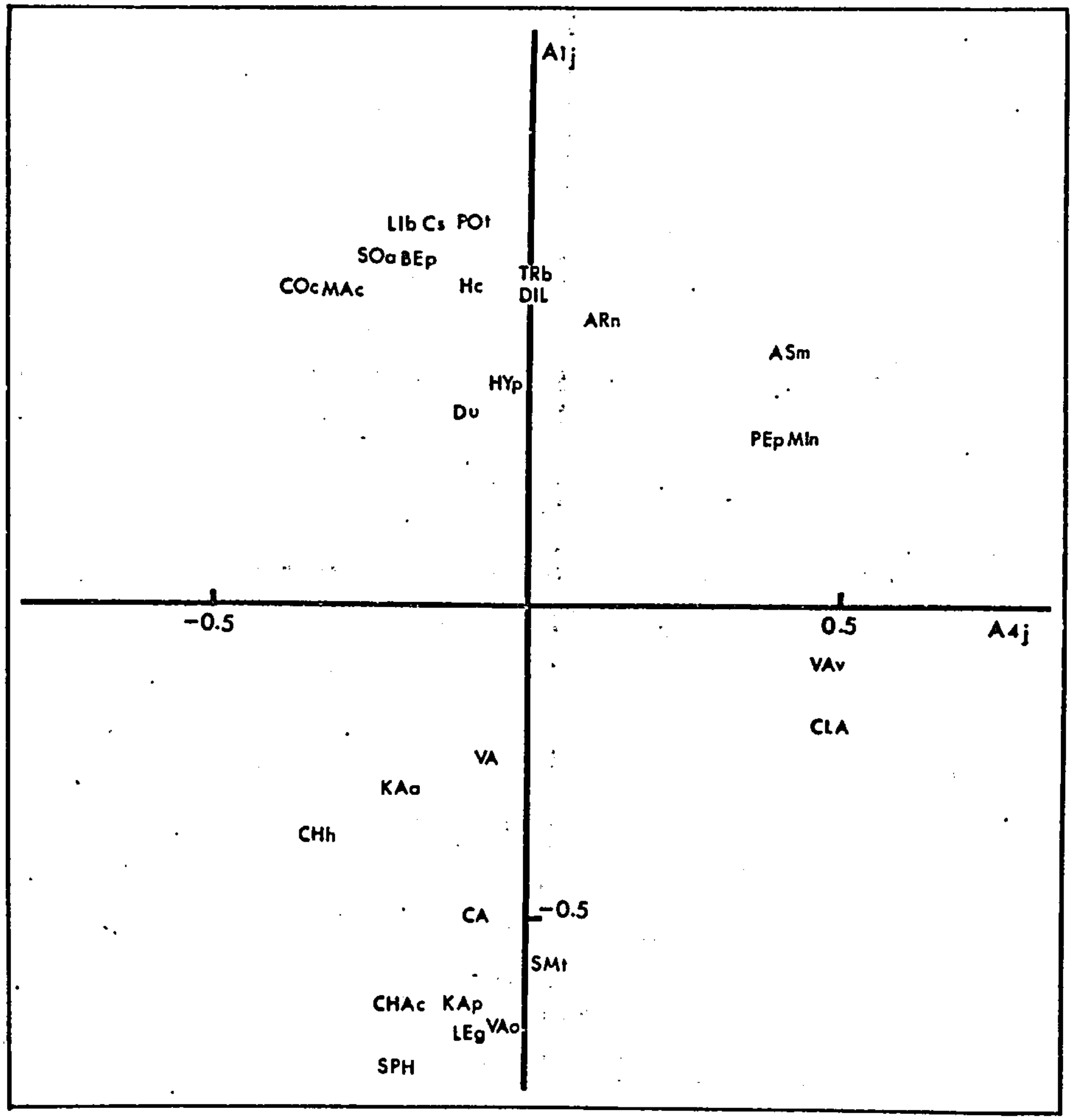

Figure 11. Ordination of 28 species common to black spruce stands, according to loading components A_{1j} and A_{4j}.

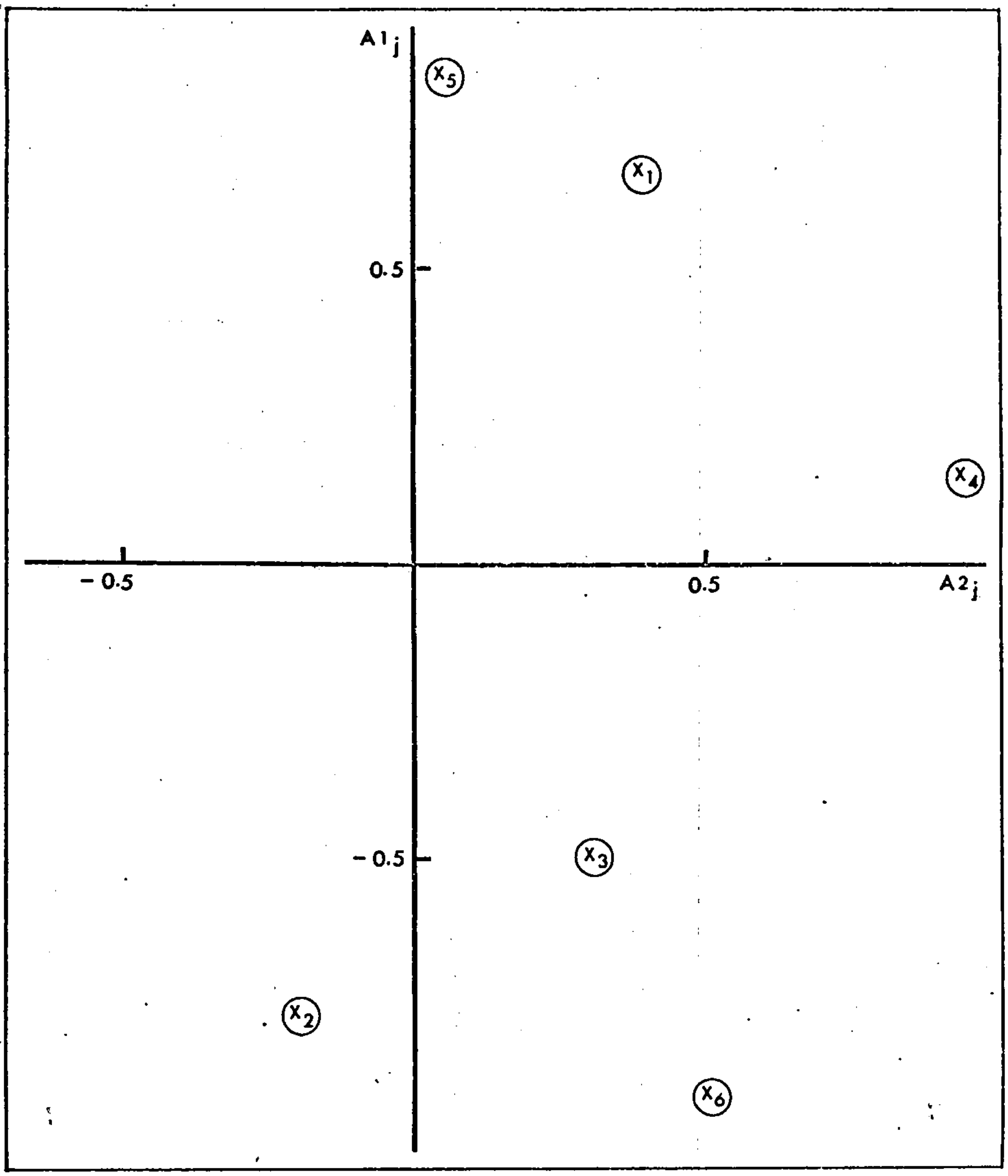

Figure 12. Component ordination of species groups according to loading components A_{1j} and A_{2j}

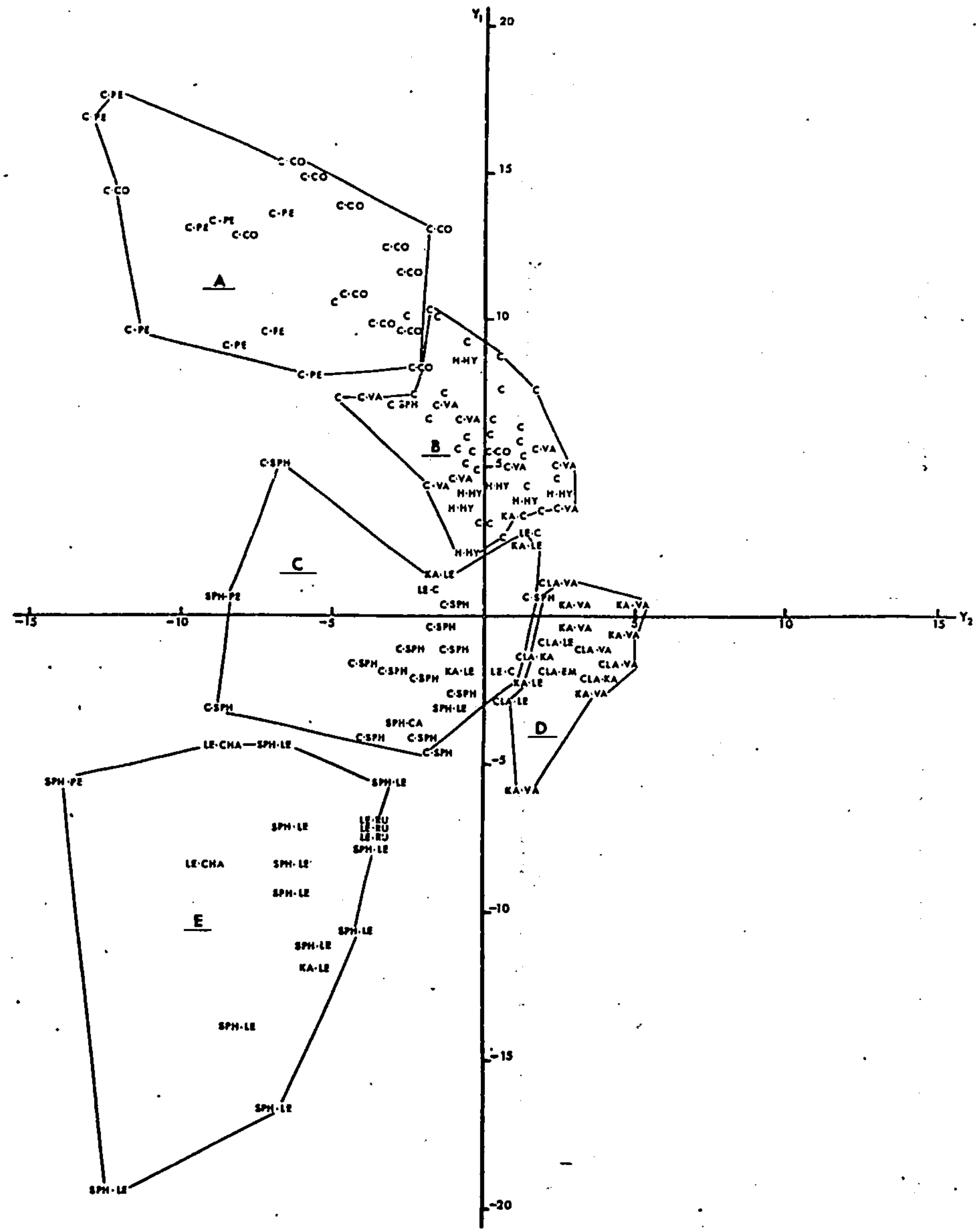

Figure 13. Vectorial ordination of sample plots identified by their site type according to Y_1 and Y_2 vectors defined by loading components on 28 species of black spruce stands.

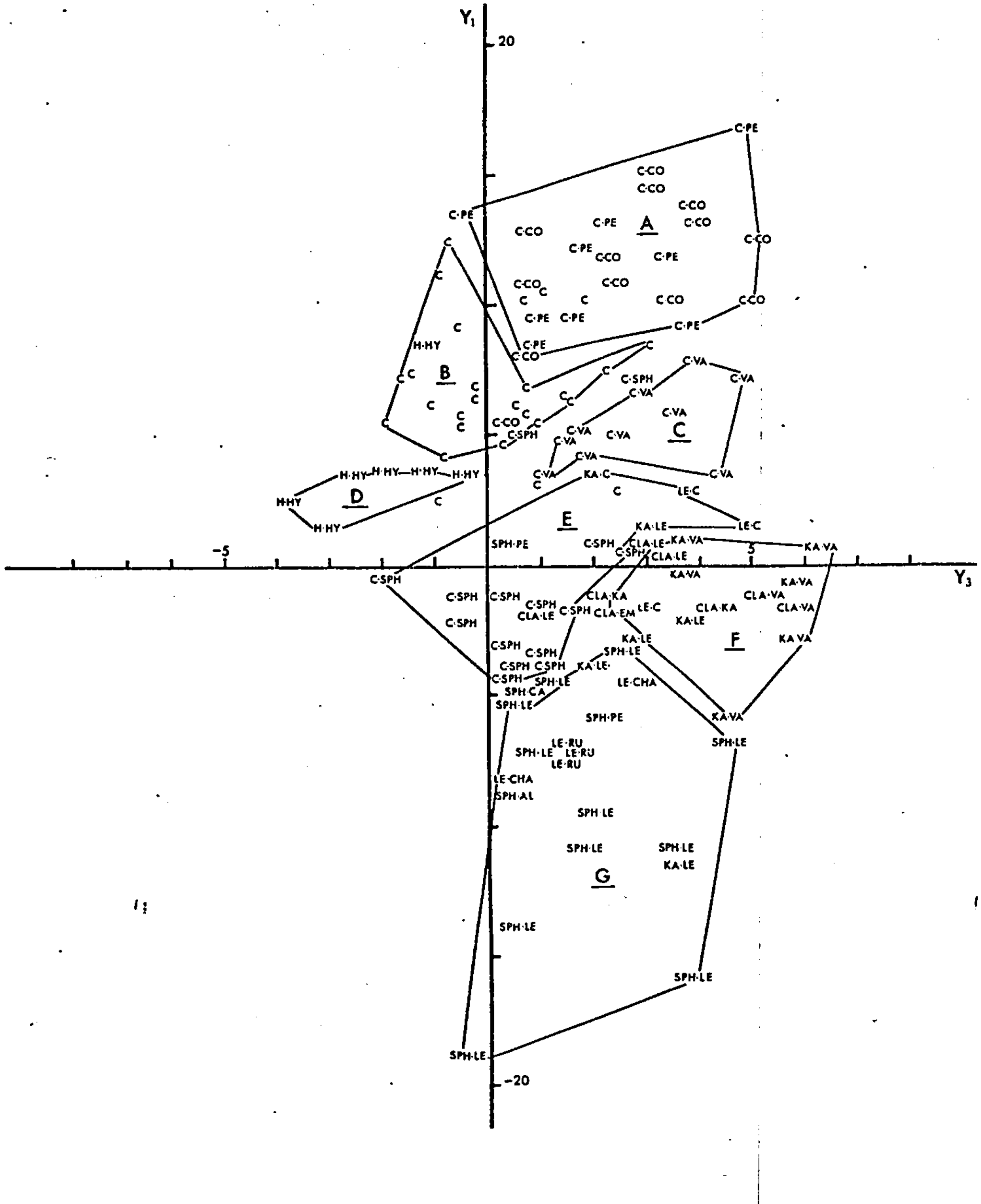

Figure 14. Vectorial ordination of sample plots identified by their site types according to Y_1 and Y_3 vectors defined by loading components on 28 species of black spruce stands.

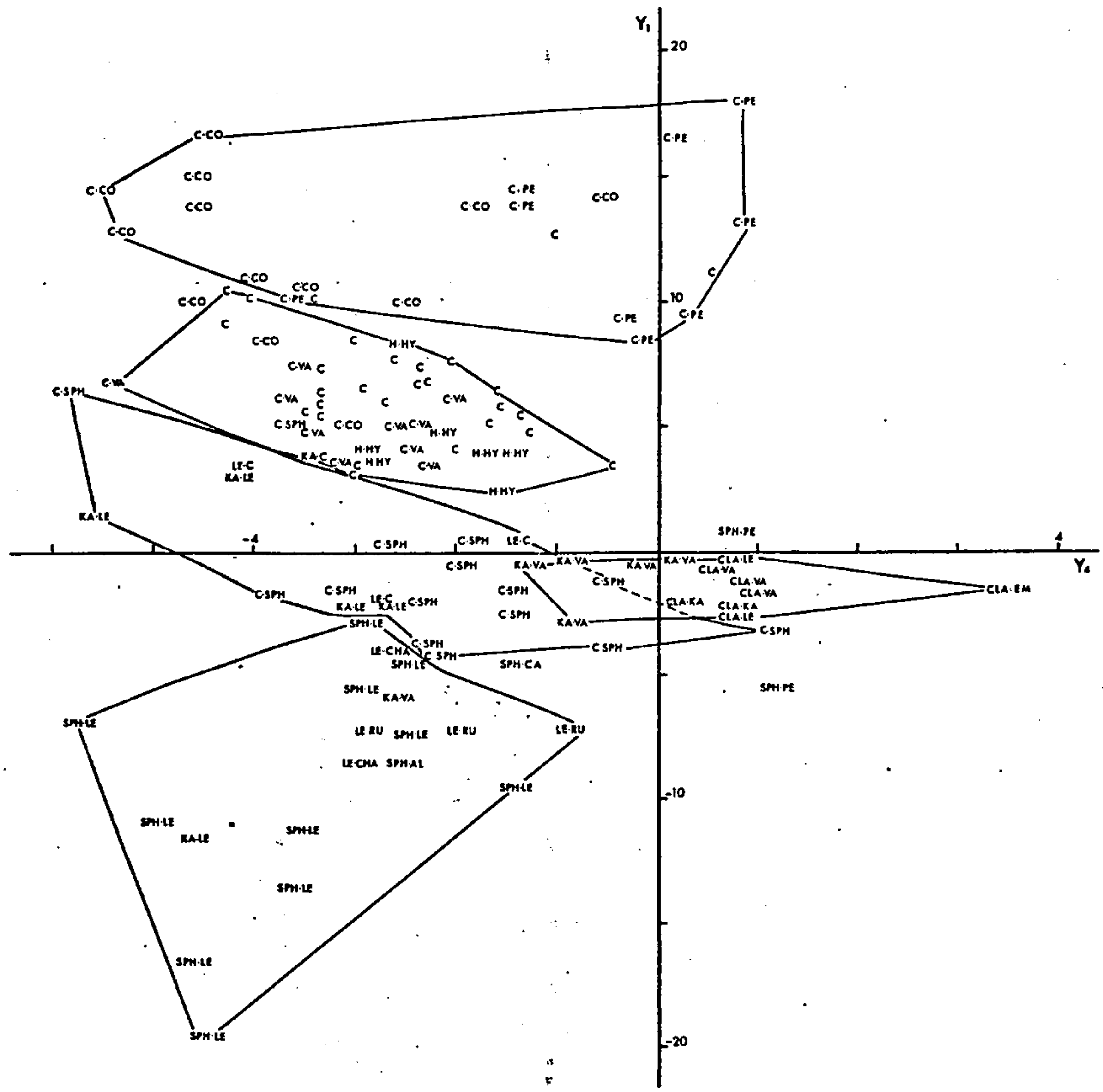

Figure 15. Vectorial ordination of sample plots identified by their site types according to Y_1 and Y_4 vectors defined by loading components on 28 species of black spruce stands.

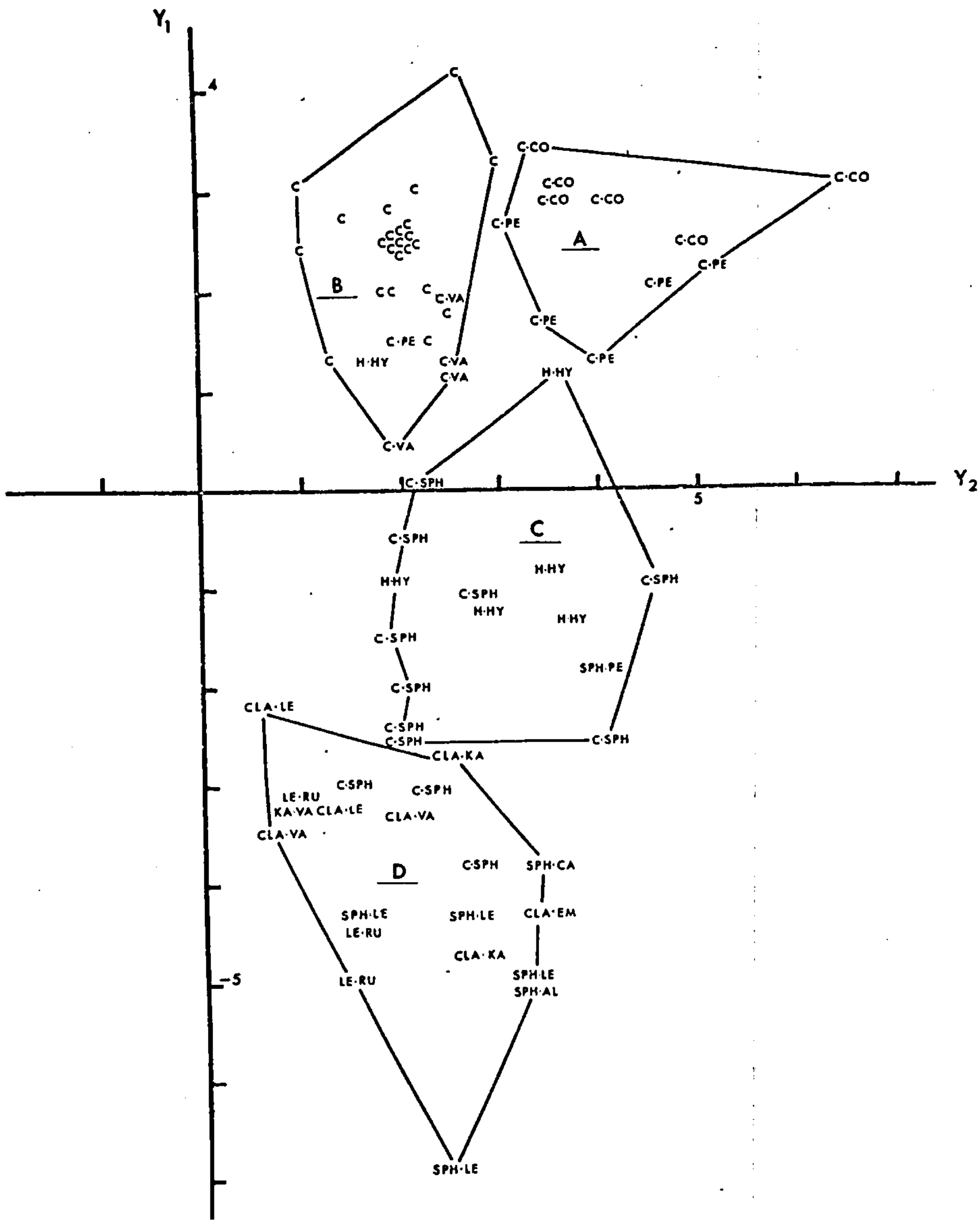

Figure 16. Vectorial ordination of sample plots, identified by their site types, according to Y_1 and Y_2 vectors defined by loading components on species groups (X_1 to X_6).

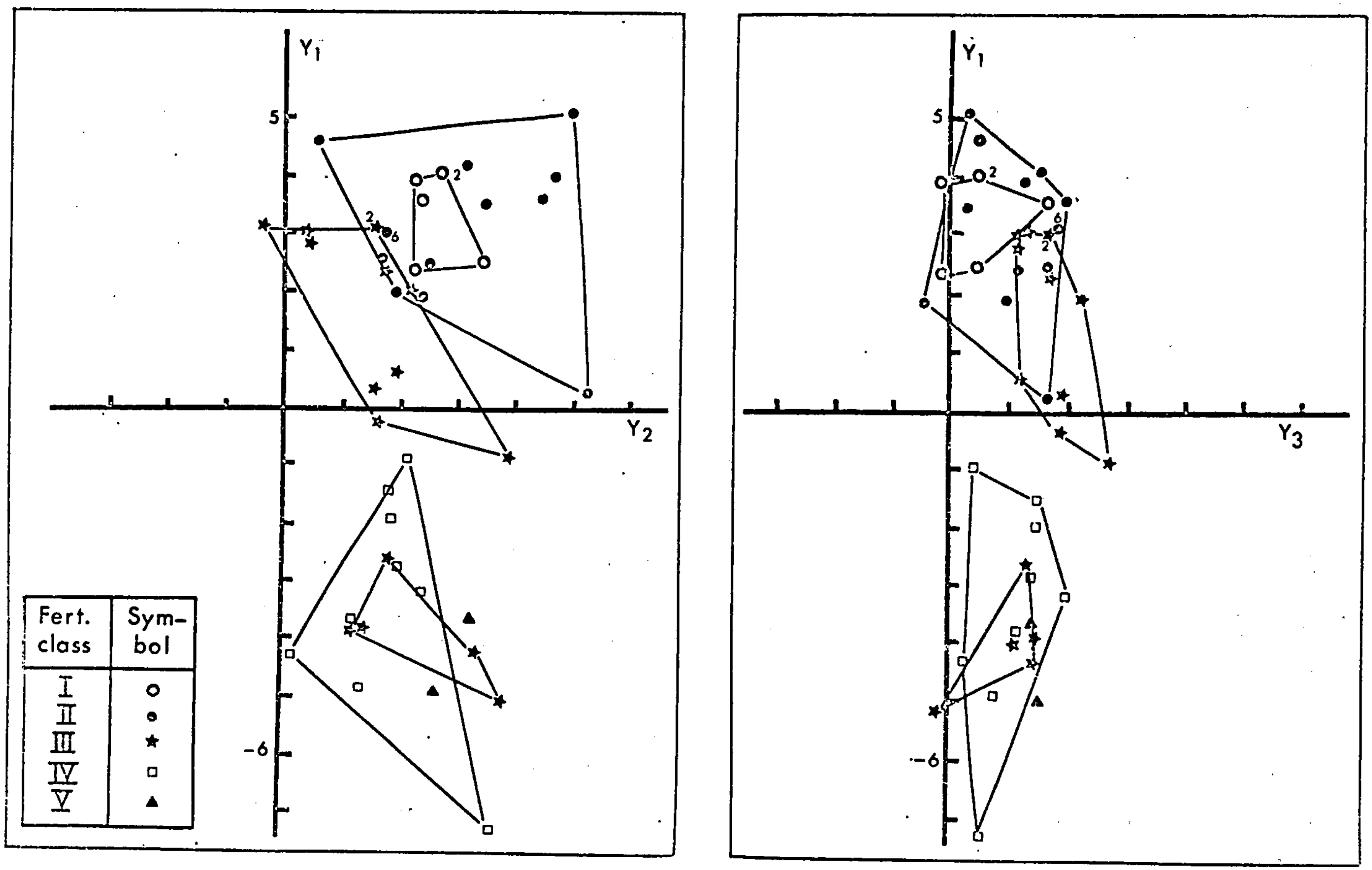

Figure 17. Fertility class distribution of the Continental region in vectorial ordination as defined by Y_1, Y_2 and Y_3 loading vectors using species groups (X_1 to X_6).

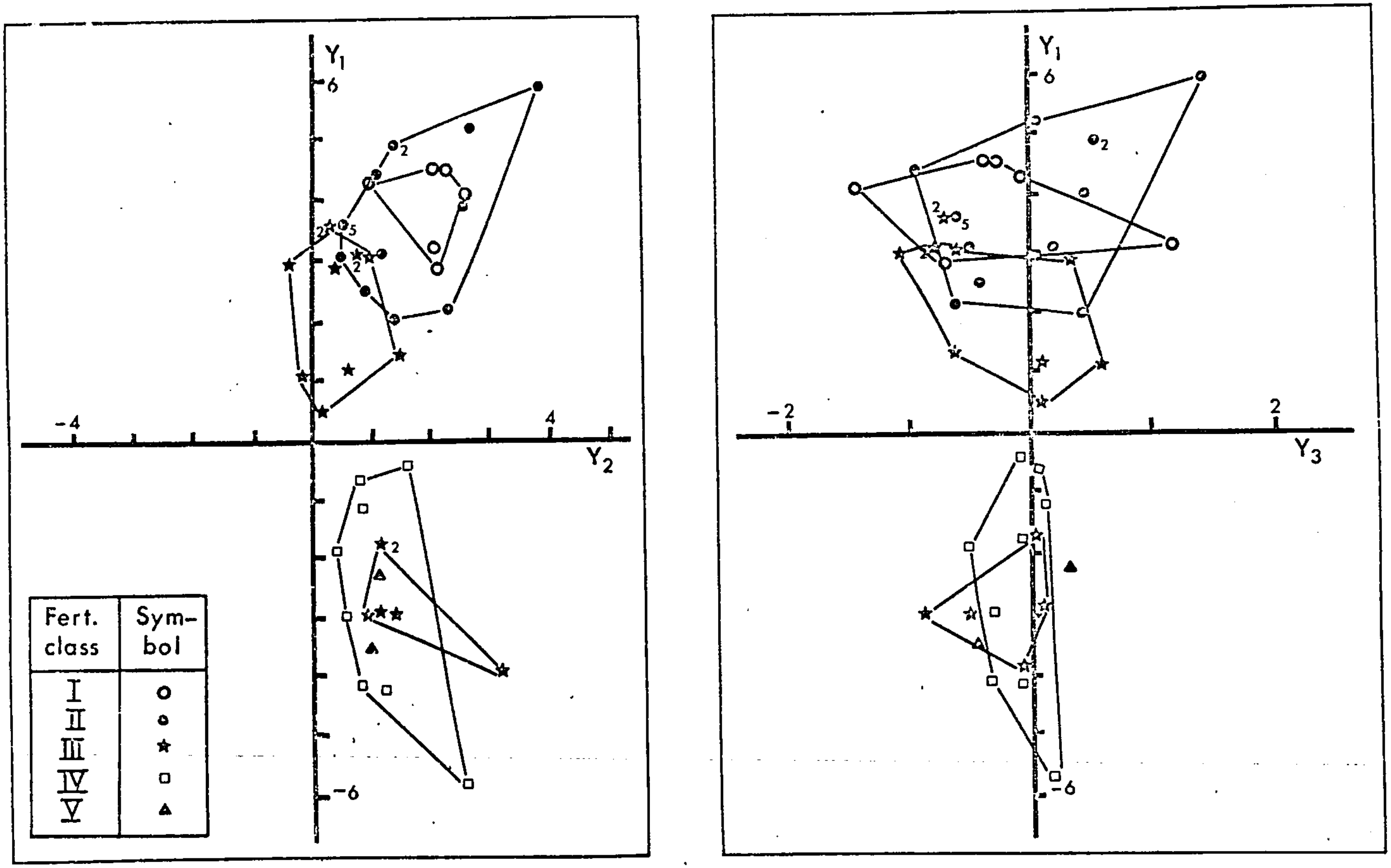

Figure 18. Fertility class distribution of the Continental region in the vectorial ordination defined by Y_1, Y_2 and Y_3 loading vectors using 5 principal species groups with regard to black spruce associations. (Groups X_1, X_2, X_4, X_5 and X_6).

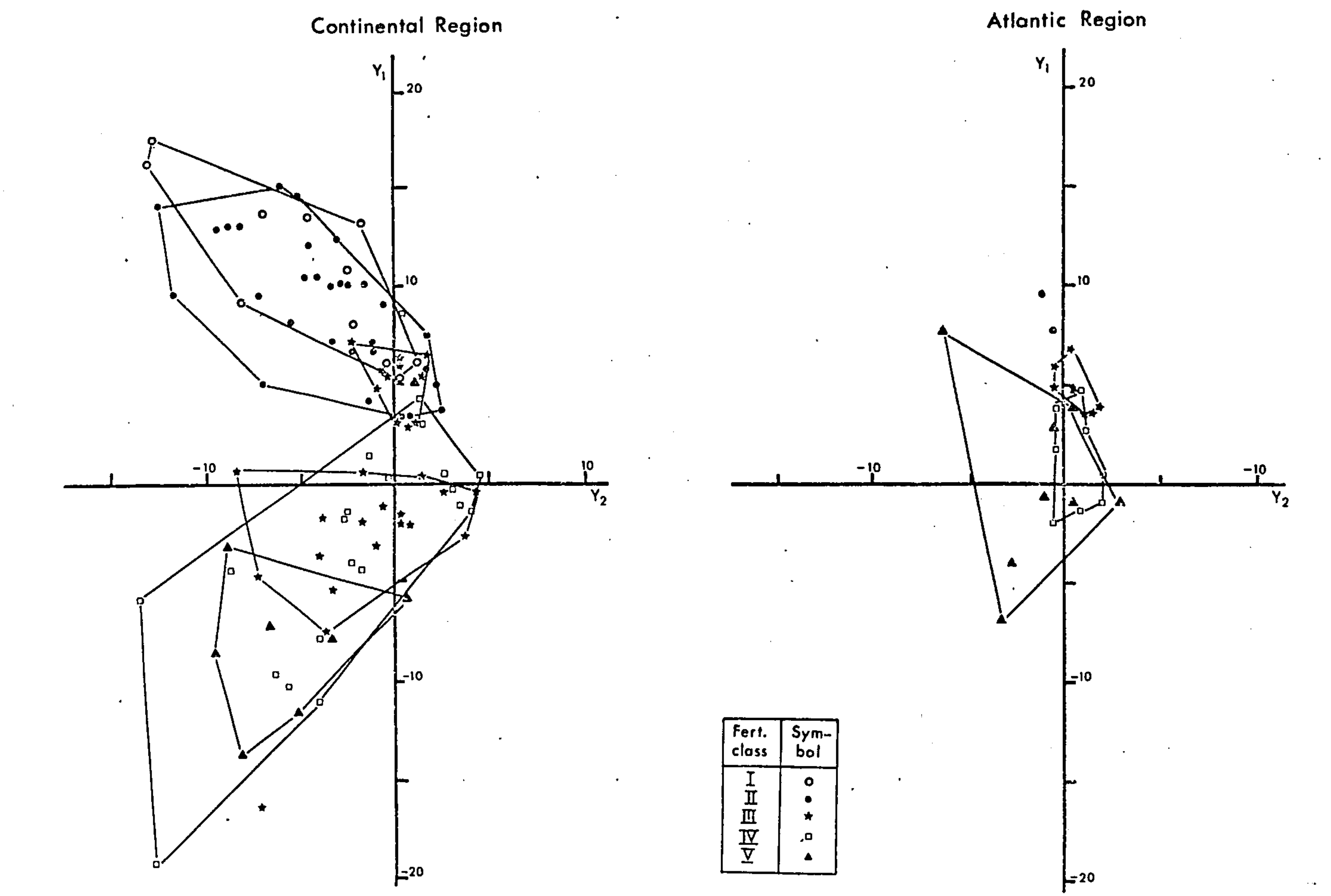

Figure 19. Fertility class comparison of the Continental and Atlantic regions, according to component analysis on interspecific dominance relations of the total region with 28 species within black spruce stands. Y_1 and Y_2 loading vectors.

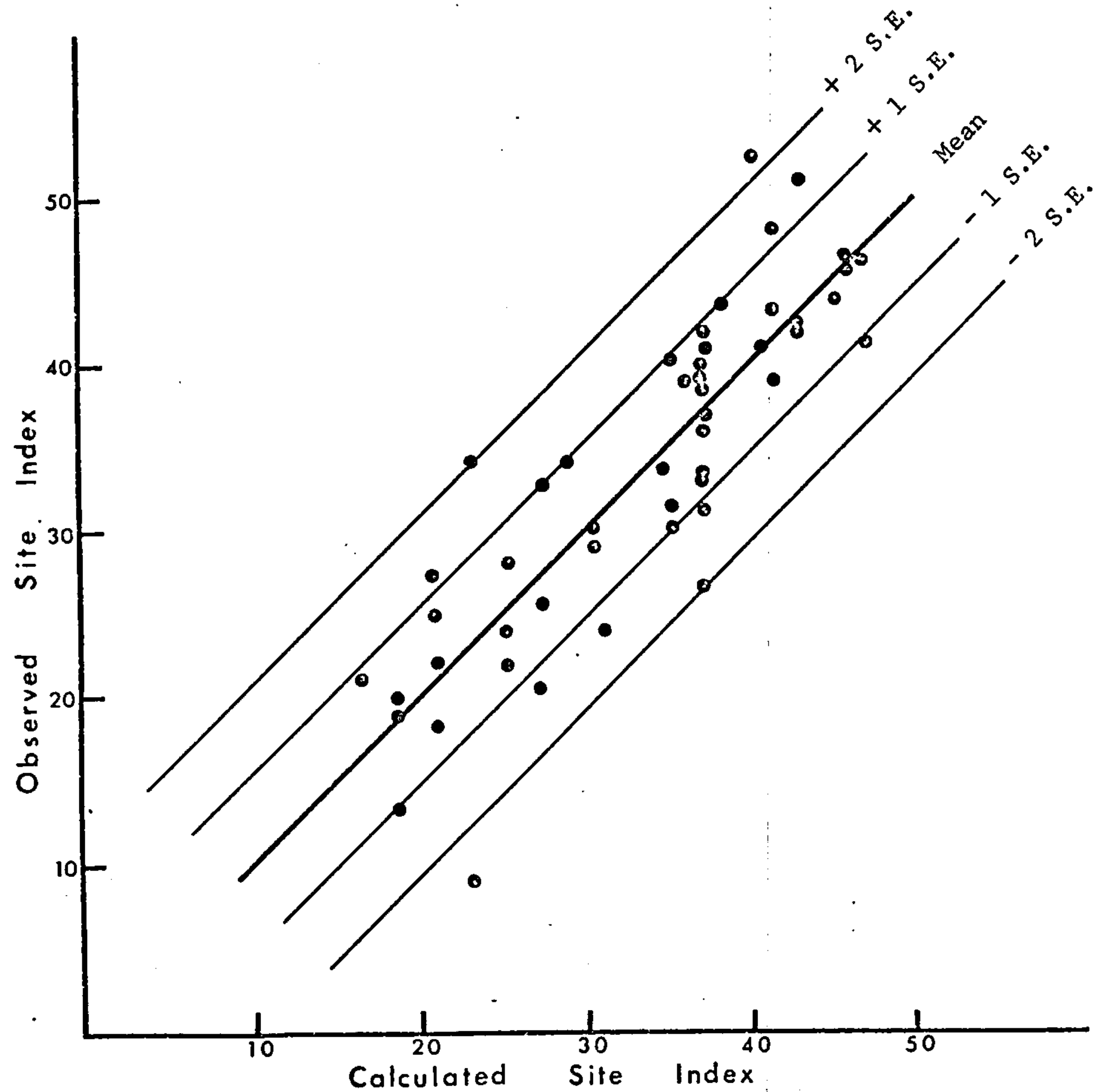

Figure 20. Comparison of observed and computed site index according to multiple regression:

$$S.I. = 29.59 + 5.63\ X_1 - 2.13\ X_6 + 5.34\ X_4 - 0.81\ X_4^2$$

$$S.E. = \pm\ 5.33\ ft.,\ R^2 = 0.74$$

A P P E N D I C E S

APPENDIX I

LIST OF PRINCIPAL SPECIES OBSERVED ON SAMPLE PLOTS

Abbreviation	Latin name	Common name
Tree Stratum		
ABb	*Abies balsamea*	Balsam fir
ACr	*Acer rubrum*	Red maple
BEl	*Betula lutea*	Yellow birch
BEp	*Betula papyrifera*	Paper birch
LAl	*Larix laricina*	Tamarack
PIg	*Picea glauca*	White spruce
PIm	*Picea mariana*	Black spruce
PINb	*Pinus banksiana*	Jack pine
PINs	*Pinus strobus*	White pine
POb	*Populus balsamifera*	Balsam poplar
POt	*Populus tremuloides*	Trembling aspen
Shrub stratum		
ACsp	*Acer spicatum*	Mountain maple
Alr	*Alnus rugosa*	Speckled alder
AM	*Amelanchier spp.*	Shadbush
CHAc	*Chamaedaphne calyculata*	Leather leaf
SIl	*Diervilla lonicera*	Bush honeysuckle
KAa	*Kalmia angustifolia*	Sheep laurel
KAp	*Kalmia polifolia*	Swamp laurel
LEg	*Ledum groenlandicum*	Labrador tea
PRp	*Prunus pensylvanica*	Pin cherry
RHc	*Rhododendron canadensis*	Rhodora
RI	*Ribes spp.*	Currant
ROa	*Rosa acicularis*	Bristly rose
RU	*Rubus spp.*	Blackberry (Raspberry)
SA	*Salix spp.*	Willow
SOa	*Sorbus americana*	Mountain ash
VA	*Vaccinium canadense*	Sour-top blueberry
	Vaccinium cespitosum	Dwarf bilberry
	Vaccinium pensylvanicum	Blueberry
VIc	*Viburnum cassinoides*	Appalachian tea
VIp	*Viburnum pauciflorum*	Edible cranberry-tree
Herb stratum		
ARn	*Aralia nudicaulis*	Wild sarsaparilla
ASc	*Aster cordifolius*	Heart-shaped aster
ASl	*Aster Lowrieanus*	Lowrie's aster
ASm	*Aster macrophyllus*	Large-leaved aster
CA	*Carex spp.*	Sedge

APPENDIX I (cont'd)

Abbreviation	Latin Name	Common name
CHh	*Chiogenes hispidula*	Snowberry
CLIb	*Clintonia borealis*	Yellow clintonia
COPg	*Coptis groenlandica*	Gold thread
COc	*Cornus canadensis*	Bunchberry
EMn	*Empetrum nigrum*	Black crowberry
EPGr	*Epigaea repens*	Mayflower
EPa	*Epilobium angustifolium*	Fireweed
EQ	*Equisetum spp.*	Horsetail
FRa	*Fragaria americana*	American strawberry
GAp	*Gaultheria procumbens*	Wintergreen
LIb	*Linnaea borealis*	Twin-flower
LY	*Lycopodium spp.*	Clubmoss
MAc	*Maianthemum canadense*	Wild lily-of-the-valley
MIn	*Mitella nuda*	Naked mitrewort
PEp	*Petasites palmatus*	Palmate sweet coltsfoot
PTa	*Pteridium aquilinum*	American bracken
SMt	*Smilacina trifolia*	Three-leaved false Solomon's seal
SOLm	*Solidago macrophylla*	Large-leaved goldenrod
STr	*Streptopus roseus*	Pink streptopus
TRb	*Trientalis borealis*	Star-flower
VAo	*Vaccinium oxycoccos*	Small cranberry
VAv	*Vaccinium Vitis-Idaea*	Mountain cranberry

Moss stratum

Cs	*Calliergon schreberi*	Schreber's moss
CLA	*Cladonia spp.*	Reindeer moss
Df	*Dicranum fuscescens*	Dicranum moss
Ds D	*Dicranum scoparium*	Broom moss
Du	*Dicranum undulatum*	Wavy dicranum
HYp	*Hylocomium proliferum*	Hylocomium moss
Hc	*Hypnum crista-castrensis*	Plume moss
LI	*Lichen spp.* (other than *Cladonia*)	Lichens
PO	*Polytrichum spp.*	Polytrichum moss
SPH	*Sphagnum spp.*	Sphagnum moss

APPENDIX II Frequency of moisture regime, black spruce associations and site types by class of site index for total sample plots.

Site index class feet	Freq.	Moist. Regime	Freq.	Black spruce Association	Freq.	Site Type*
54.9	3	2	9	Herb and Moss	5	*Calliergon-Cornus* (C-CO)**
to	5	3	2	Moss	4	*Calliergon-Petasites* (C-PE)
45.0	3	4			1	*Calliergon* (C)
					1	*Calliergon-Vaccinium* (C-VA)
	2	0	13	Herb and Moss	8	*Calliergon-Cornus*
	2	1			5	*Calliergon-Petasites*
44.9	13	2	17	Moss	10	*Calliergon*
to	9	3	3	Moss and Dwarf Shrub	6	*Calliergon-Vaccinium*
	2	4			2	*Calliergon-Sphagnum* (C-SPH)
35.0	2	5	1	Peat Moss and Dwarf Shrub	1	*Hypnum-Hylocomium* (H-HY)
	3	6			1	*Kalmia-Calliergon* (KA-C)
	1	7			1	*Sphagnum-Ledum* (SPH-LE)
	3	0	16	Moss	14	*Calliergon*
	7	1	10	Moss and Dwarf Shrub	2	*Calliergon-Vaccinium*
	7	2			5	*Calliergon-Sphagnum*
34.9	3	3	5	Peat Moss and Dwarf Shrub	3	*Ledum-Calliergon* (LE-C)
to	4	4			2	*Kalmia-Ledum* (KA-LE)
	1	5			3	*Kalmia-Vaccinium* (KA-VA)
25.0	3	6	3	Lichen and Dwarf Shrub	3	*Sphagnum-Ledum*
	3	7			1	*Ledum-Rubus* (LE-RU)
	2	8			1	*Sphagnum-Petasites* (SPH-PE)
	1	9				
	7	0			3	*Calliergon*
	1	1	7	Moss	4	*Hypnum-Hylocomium*
	4	2	8	Moss and Dwarf Shrub	6	*Calliergon-Sphagnum*
	3	3			2	*Kalmia-Ledum*
24.9	2	4	6	Peat Moss and Dwarf Shrub	2	*Kalmia-Vaccinium*
to	1	5			1	*Ledum-Chamaedaphne* (LE-CHA)
	1	6	8	Lichen and Dwarf Shrub	3	*Cladonia-Vaccinium* (CLA-VA)
15.0	10	8			1	*Cladonia-Ledum* (CLA-LE)
	1	9	1	Peat Moss and herb***	1	*Cladonia-Kalmia* (CLA-KA)
					1	*Cladoni-Empetrum* (CLA-EM)
					5	*Sphagnum-Ledum*
					1	*Sphagnum-Petasites*
	2	0			1	*Calliergon-Vaccinium*
	1	1	3	Moss	2	*Hypnum-Hylocomium*
	2	2	3	Moss and Dwarf Shrub	2	*Calliergon-Sphagnum*
14.9	1	4			1	*Kalmia-Ledum*
to	1	6	6	Peat Moss and Dwarf Shrub	2	*Ledum-Rubus*
	2	7			1	*Kalmia-Vaccinium*
2.5	6	8	3	Lichen and Dwarf Shrub	1	*Ledum-Chamaedaphne*
	1	9			2	*Sphagnum-Ledum*
			1	Peat Moss and herb***	1	*Cladonia-Kalmia*
					1	*Cladonia-Ledum*
					1	*Sphagnum-Carex* (SPH-CA)
					1	*Sphagnum-Alnus* (SPH-AL)

* Site type as defined by Linteau[74] and Lafond[68,70].
** Site type abbreviations.
*** Proposed site types and associations.

APPENDIX III — Mean percent of covering of the strata according to three site factors.

	CLASS	STRATA: Trees (1)	Shrubs (2)	Herbs (3)	Mosses (4)	Number of plots by class (1-2-4)	(3)*
Site Index	2.5-14.9	47%	49.1%	14.6%	96%	16	12
	15 -24.9	50	40.7	6.7	96	30	16
	25 -34.9	64	31.4	8.8	92	34	24
	35 -44.9	77	14.9	17.0	85	34	22
	45 -54.9	79	7.6	9.1	76	11	6
Moisture Regime	0	35	44	1.9	87	14	9
	1	65	26	4.4	84	11	7
	2	77	16	8.8	86	29	18
	3	84	3.1	6.7	91	20	15
	4	68	23	13.1	89	12	6
	5	64	24	21.0	94	4	2
	6	63	42	13.6	95	8	5
	7	58	34	28.1	94	6	6
	8	45	60	15.0	96	18	12
	9	22	90	-	98	3	0
% of Tree Cover	0 - 20	-	89	-	99	5	-
	21 - 40	-	64	9.2	91	23	14
	41 - 60	-	52	8.0	94	25	14
	61 - 80	-	11.5	14.1	88	40	23
	81 -100	-	3.1	11.2	88	32	29

* The number of sample plots is different in the case of the herbaceous stratum because the estimate of herb cover was made on only 80 of the 125 plots.

APPENDIX IV Mean percent of dominance of some vascular species of black spruce stands by fertility classes.

Strata	No. of Plots	11	34	34	30	16
	Species	Fertility Class				
		I	II	III	IV	V
Tree and Shrub	BEp	6.2	3.3	1.1	0.9	0.4
	POt	3.2	1.6	0.9	0.1	0.1
	ALr	1.1	2.5	1.7	0.9	2.3
	CHAc	0	0	2.4	5.0	13.4
	DIl	2.0	1.4	0	0	0
	KAa	1.7	4.9	10.0	10.2	8.2
	KAp	0	0	1.1	1.5	3.5
	LEg	1.6	3.0	16.3	18.6	20.1
	ROa	1.8	1.1	0.2	0.1	0.1
	SOa	1.3	1.3	0.1	0.1	0
	VA	3.2	7.2	11.8	12.7	12.6
	VIc	0.6	0.5	0.6	0.2	0.3
	VIp	1.1	0.4	0	0	0.1
Herb	ARn	2.9	1.6	0	0	0
	ASm	3.8	1.0	0	0	0.1
	CA	0.9	1.2	3.3	6.0	12.5
	CHh	2.0	2.7	2.9	5.8	12.0
	CLIb	1.7	2.1	0.4	1.1	3.1
	COc	12.2	11.9	2.8	2.5	2.5
	COPg	5.4	2.7	1.9	1.2	2.1
	LIb	4.0	3.6	0.9	0.5	0.6
	MAc	1.9	2.0	0.4	0.3	0.7
	MIn	3.2	1.3	0	0.1	0.3
	PEp	1.5	1.3	0.3	0.5	0.1
	PTa	2.4	1.1	0	0	0
	SMt	0	0.2	0.3	1.5	2.1
	TRb	1.3	1.1	0	0	0
	VAo	0	0	0.6	1.9	2.0
	VAv	0	0.2	0.4	0.7	0.9
Moss	Cs	60.1	56.7	50.7	32.3	27.3
	CLA	1.7	3.8	7.7	18.6	12.8
	Du	4.2	3.7	4.5	2.9	1.7
	Hc	6.5	11.3	7.3	4.7	2.9
	HYp	3.6	5.2	3.0	8.3	8.4
	SPH	1.3	6.6	19.3	29.5	42.5

APPENDIX V Mean percent of dominance of some vascular species of black spruce stands by moisture regime class.

Strata	No. of Plots	14	11	29	20	12	4	8	6	18	3
	Species	Moisture Regime									
		0	1	2	3	4	5	6	7	8	9
Tree and Shrub	BEp	0.8	0.9	2.9	4.8	2.2	3.7	0	0.4	0.5	0
	POt	0.3	1.3	1.4	1.8	2.0	0.6	0	0.4	0	0
	ALr	0.3	1.5	1.0	0.8	1.0	1.8	7.5	2.9	3.0	0.8
	CHAc	2.1	0	0	0	0	0	0.3	5.4	12.1	56.6
	DIl	0.1	0.2	1.4	0.6	0.4	3.1	0	0	0	0
	KAa	13.7	14.5	7.7	0.8	6.4	7.5	4.6	2.9	10.1	9.1
	KAp	1.0	0	0	0	0.2	0.6	0.9	1.2	1.9	24.1
	LEg	11.6	7.5	3.2	1.2	9.7	11.2	31.5	21.2	30.4	37.5
	ROa	0.3	1.5	0.3	0.6	1.4	1.8	0	0.4	0.2	0
	SOa	0.3	0	1.0	1.3	0.4	0.6	0.3	0	0	0
	VA	29.2	11.8	5.3	2.5	11.6	1.8	5.0	7.5	12.5	23.2
	VIc	0.1	0.2	0.6	0.1	0.4	0	0.6	0.4	0.6	4.1
	VIp	0	0	0.2	0.6	0.4	1.2	0	0	0.1	0
Herb	ARn	0.3	0	0.6	1.0	2.5	0.6	0	2.0	0	0
	ASm	0.1	0	0.6	1.0	1.6	1.2	0	2.5	0.2	0
	CA	0.3	0.4	0.1	0.5	1.2	1.2	3.1	7.0	16.8	44.1
	CHh	2.1	1.8	3.6	2.6	6.8	5.0	3.7	5.8	10.0	9.1
	CLIb	0.3	0.4	1.2	2.0	0.8	1.2	0.9	0.8	2.7	11.6
	COPg	0.3	1.8	0.8	2.6	4.1	4.3	1.3	2.5	4.3	4.1
	COc	3.0	6.1	7.2	7.5	11.0	8.1	7.5	3.3	2.1	0
	LIb	0.3	1.1	2.5	3.1	2.2	3.7	0.9	0.8	0.8	0
	MAc	0.5	0.9	1.0	2.1	1.2	1.8	0.3	0.4	0.9	0
	MIn	0	0	0.1	0.3	2.9	6.2	0.6	0.8	0.5	0
	PEp	0.1	0.2	0.6	1.1	0.4	3.7	0.3	0.8	1.1	0
	PTa	0.1	1.3	0.2	0.7	2.0	0	0.3	0	0	0
	SMt	0	0.2	0	0	0.4	0	1.2	2.0	3.3	5.5
	TRb	0	0	0.4	1.1	0.6	1.2	0.3	1.4	0	0
	VAo	0	0.2	0	0	0	0.6	0.6	1.2	2.2	18.3
	VAv	1.2	0.4	0.2	0.2	0.4	1.2	0.3	1.2	0.2	0
Moss	Cs	26.4	61.1	57.1	59.2	53.3	55.0	45.6	32.5	22.7	5.8
	CLA	55.1	15.2	3.1	1.8	1.6	1.2	1.2	3.7	2.7	1.6
	Du	3.0	2.2	5.6	2.2	7.2	2.5	2.8	2.0	1.6	0.3
	HYp	0.3	2.7	11.3	7.2	5.4	8.7	9.0	2.9	0.4	0
	Hc	2.1	7.2	8.5	19.1	6.2	2.5	1.3	3.7	1.6	0.8
	SPH	1.4	0.6	1.9	2.7	17.7	23.1	38.4	47.5	64.4	90.0

APPENDIX VI   Mean percent of dominance of some vascular species of black spruce stands by tree density classes.

Strata	No. of Plots	5	23	24	41	32
	Species	Percent of Tree Cover				
		0 to 20	21 to 40	41 to 60	61 to 80	81 to 100
Tree and Shrub	BEp	0	0.8	1.0	2.4	3.5
	POt	0	0.2	0.3	1.3	1.9
	ALr	0.5	2.3	3.6	0.9	1.2
	CHAc	46.0	6.7	2.7	0	0
	DIl	0	0	0	1.4	0.5
	KAa	21.0	14.8	13.3	4.3	0.7
	KAp	9.5	2.5	1.4	0	0
	LEg	42.0	23.2	28.1	2.5	1.3
	ROa	0.5	0.2	0.7	0.7	0.7
	SOa	0	0.1	0.1	0.7	1.1
	VA	26.5	25.0	10.0	6.2	2.1
	VIc	2.5	0.3	0.4	0.5	0.3
	VIp	0.5	0	0	0.4	0.3
Herb	ARn	0	0.1	0.1	1.0	1.3
	ASm	0	0.1	0.3	0.9	1.1
	CA	27.0	5.4	6.1	2.5	1.0
	CHh	16.0	5.5	5.4	4.1	2.3
	CLIb	9.0	0.8	1.6	1.1	1.7
	COPg	3.0	2.1	3.1	2.0	2.0
	COc	1.0	3.4	6.6	3.0	4.2
	LIb	0.5	0.3	1.3	2.9	1.8
	MAc	0	0.8	0.4	1.0	1.8
	MIn	0.5	0	0.4	1.2	0.8
	PEp	0	0.2	0.8	0.9	0.9
	PTa	0	0	0	1.2	0.4
	SMt	5.5	1.5	1.1	0.1	0.2
	TRb	0	0	0.1	0.4	0.9
	VAo	9.5	1.3	1.3	0	0
	VAv	0	0.8	0.7	0.3	0.3
Moss	Cs	18.0	23.5	39.6	52.3	62.5
	CLA	7.5	37.0	5.8	2.4	1.5
	Du	2.0	2.3	2.2	5.6	2.3
	HYp	0.5	1.5	2.2	7.9	9.0
	Hc	0	1.8	3.5	8.9	12.5
	SPH	70.5	26.9	40.2	9.5	4.2

APPENDIX VII Mean percent of cover by fertility and by tree stratum cover classes of species groups

Species groups	Fertility Class					Tree Stratum Cover Class				
	I	II	III	IV	V	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
X_1	4.0	2.0	0.0	0.2	0.0	-	0.4	0.0	0.7	1.6
X_2	0.4	1.5	11.2	18.5	18.5	-	29.0	26.9	4.7	0.7
X_3	1.6	2.7	2.4	4.8	10.3	-	5.7	6.1	4.8	2.0
X_4	5.1	7.3	1.5	0.4	1.4	-	0.4	0.5	4.1	4.2
X_5	53.1	62.8	65.8	40.6	30.4	-	20.6	39.8	62.3	65.5
X_6	3.2	6.9	17.8	46.9	60.9	-	63.0	50.6	15.7	10.0
No. of plots	6	19	22	18	20	0	12	12	22	29

APPENDIX VIII Mean percent of cover by soil moisture classification of species groups

M.R.	0	1	2	3	4	5	6	7	8	9
No. of plots	8	7	17	15	6	2	5	6	9	0
X_1	0.6	0.0	0.9	2.0	0.0	7.6	0.0	0.1	0.0	0.0
X_2	18.7	7.3	1.4	1.3	3.0	13.1	21.4	23.3	28.8	0.0
X_3	1.4	0.3	2.3	1.5	7.1	2.0	9.1	9.0	9.2	0.0
X_4	0.2	2.1	3.2	3.0	4.7	10.8	3.0	5.6	1.2	0.0
X_5	18.0	71.4	64.9	68.8	59.8	56.0	46.0	40.0	30.2	0.0
X_6	54.9	8.7	8.4	10.5	22.5	22.9	46.4	32.3	59.0	0.0

Sites	Eu-xeric	Subxeric	Mesic	Subhydric	Euhydric
Groups					
X_1	0.6*	0.6	1.4	2.2	0.0
X_2	18.7	3.1	1.8	19.0	26.1
X_3	1.4	1.7	3.1	7.1	9.1
X_4	0.2	2.8	3.5	5.3	2.8
X_5	18.0	66.8	66.2	48.9	34.3
X_6	54.9	8.5	13.9	39.5	52.3

* Weighted mean according to the number of plots by moisture regime.

APPENDIX IX Correlation coefficient matrix between the species dominance and certain site factors - total region

VARIABLE	NO.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
S.I.	1	.55	-.29	.46	.48	.14	-.40	.40	-.17	-.42	-.37	.30	.46	-.10	.15	.29
% Cover	2		-.74	.41	.48	-.02	-.52	.28	-.46	-.47	-.63	.14	.40	-.50	-.05	.29
H.R.	3			-.28	-.30	.23	.52	-.17	-.02	.51	.51	-.07	-.21	-.08	.17	-.01
RFp	4				.36	-.06	-.30	.17	-.11	-.30	-.44	.01	.47	-.23	.03	.14
POt	5					.03	-.25	.21	-.17	-.30	-.33	.31	.31	-.17	.04	.27
AIr	6						-.08	.10	.03	.00	.20	.17	.07	-.04	.05	.09
CHAc	7							-.14	.19	.73	.48	-.09	-.19	.12	.08	-.01
DII	8								-.15	-.17	-.29	.32	.34	-.08	.05	.58
KAn	9									.05	.24	-.37	-.17	.54	.19	-.26
KAp	10										.48	-.16	-.23	.13	.09	-.14
LEg	11											-.11	-.27	.32	.06	-.21
ROa	12												.18	-.18	-.16	.50
SOe	13													-.12	.09	.31
VA	14														.17	-.16
VIc	15															-.15

VARIABLE	NO.	17	18	19	20	21	22	23	24	25	26
S.I.	1	.41	.36	-.25	-.37	.20	.34	.50	.47	.50	.23
% Cover	2	.25	.20	-.29	-.26	.30	.08	.22	.38	.38	.16
H.R.	3	-.06	.06	.63	.44	.19	.22	-.10	-.09	-.13	.19
RFp	4	.12	.08	-.28	-.20	.13	.12	.33	.30	.23	.03
POt	5	.27	.20	-.23	-.29	.10	.04	.25	.38	.40	.13
AIr	6	.33	.28	.23	.11	.11	.27	.16	.23	.17	.37
CHAc	7	-.13	-.12	.49	.31	.29	-.01	-.28	-.22	-.25	-.03
DII	8	.48	.44	-.04	-.09	.26	.08	.37	.55	.41	.31
KAn	9	-.24	-.31	-.06	.13	-.12	-.04	-.08	-.25	-.28	-.30
KAp	10	-.15	-.13	.45	.22	.15	-.09	-.29	-.29	-.26	-.10
LEg	11	-.22	-.15	.39	.35	.01	.06	-.13	-.27	-.18	-.03
ROa	12	.46	.54	.12	-.12	.22	.11	.20	.27	.40	.56
SOe	13	.29	.26	-.13	-.13	.36	.06	.33	.37	.43	.20
VA	14	-.10	-.14	.00	.01	-.09	.09	.03	-.14	-.08	-.19
VIc	15	.01	-.13	.12	.08	.12	.45	.27	.08	.18	-.12
VIp	16	.33	.50	.05	-.07	.24	.15	.23	.46	.35	.48
ABu	17		.57	.02	-.08	.31	.16	.21	.36	.46	.41
ASa	18			.12	-.09	.25	.17	.22	.39	.29	.71
CA	19				.30	.50	.16	-.08	-.07	.04	.23
Chh	20					.14	.08	.02	-.02	.09	-.01
CLib	21						.34	.27	.29	.42	.24
COrg	22							.42	.31	.45	.14
COc	23								.62	.45	.16
LIb	24									.55	.32
MAc	25										.21

VARIABLE	NO.	27	28	29	30	31	32	33	34	35	36	37	38
S.I.	1	.22	.30	-.32	.50	-.61	-.29	-.28	.48	.26	-.01	.29	-.44
% Cover	2	.15	.17	-.34	.35	-.49	-.11	-.55	.57	.20	.42	.50	-.44
H.R.	3	.12	-.11	.63	-.04	.62	-.01	-.46	-.33	-.37	-.17	-.25	.85
RFp	4	-.02	.25	-.35	.32	-.37	-.05	-.16	.27	.07	.23	.32	-.40
POt	5	.12	.21	-.28	.30	-.30	-.07	-.21	.34	.19	.12	.42	-.46
AIr	6	.26	-.07	.29	.13	.13	-.03	-.14	-.12	-.27	-.06	.03	.19
CHAc	7	-.08	-.10	.44	-.16	.69	-.11	-.06	-.34	-.20	-.25	-.28	.58
DII	8	.45	.37	-.19	.31	-.17	-.12	-.15	.25	.20	-.03	.09	-.24
KAn	9	-.34	-.03	-.11	-.30	-.02	-.07	.30	-.16	-.02	-.21	-.22	.06
KAp	10	-.06	-.12	.45	-.19	.69	.07	-.03	-.35	-.22	-.28	-.26	.60
LEg	11	.05	-.22	.43	-.26	.57	.02	.07	-.38	-.25	-.31	-.38	.61
ROa	12	.50	.09	.00	.33	-.05	-.06	-.12	.17	-.02	.04	.12	-.19
SOe	13	.17	.30	-.23	.41	-.23	-.09	-.20	.18	.12	.16	.28	-.27
VA	14	-.09	.04	-.09	-.14	.01	-.17	.43	-.11	.04	-.27	-.27	.01
VIc	15	-.19	.11	.03	.07	.05	-.14	-.09	-.15	.19	-.13	-.09	.19
VIp	16	.52	.16	-.06	.41	-.09	-.10	-.19	.16	.15	.06	.09	-.14
ABu	17	.21	.23	-.10	.39	-.15	-.11	-.15	.17	.04	-.05	.16	-.23
ASa	18	.69	.14	-.01	.68	-.03	.01	-.17	.13	-.05	.07	.16	-.13
CA	19	.23	-.04	.55	-.04	.72	-.07	-.23	-.41	-.34	-.25	-.31	.61
Chh	20	-.04	-.14	.21	-.13	.30	.11	-.21	-.27	-.21	.00	-.15	.50
CLib	21	.18	.09	.09	.39	.27	-.19	-.27	.08	-.14	-.06	.04	.09
COrg	22	.15	-.01	-.01	.35	.01	-.27	-.24	.04	-.08	-.14	.04	.13
COc	23	.21	.38	-.20	.27	-.24	-.15	-.21	.31	.16	.09	.14	-.18
LIb	24	.39	.20	-.12	.39	-.18	-.13	-.26	.31	.14	.07	.31	-.27
MAc	25	.27	.16	-.23	.49	-.19	-.28	-.24	.25	.11	-.04	.23	-.21
HIm	26	.63	.18	.13	.37	.07	.06	-.24	.00	-.05	.09	.01	-.01
FFp	27		.08	.03	.35	.12	.03	-.18	.07	-.11	.01	.07	-.01
PTe	28			-.14	-.03	-.12	-.12	-.11	.10	.22	-.03	-.02	-.16
SHt	29				-.13	.58	.04	-.15	-.42	-.22	-.23	-.30	.66
TBb	30					-.19	-.14	-.24	.16	.01	.11	.33	-.22
VAo	31						.06	-.10	-.46	-.33	-.29	-.36	.63
VAv	32							.22	-.07	-.10	-.02	-.05	.01
CLA	33								-.29	-.03	-.33	-.23	-.29
Ca	34									.22	.22	.35	-.50
Du	35										-.02	-.01	-.25
HYp	36											.33	-.27
Nr	37												-.40
SPH	38												

Correlation coefficient are significant at 5 % level of probability for 0.17 and at 1% level of probability for 0.23.

APPENDIX X Correlation coefficient matrix between the dominance of species groups and certain site factors.

CONTINENTAL REGION

VARIABLE	NO.	2	3	4	5	6	7	8	9
S. I.	1	.69	-.41	.76	-.66	-.10	.58	.43	-.75
% Cover	2		-.40	.66	-.88	-.17	.40	.71	-.81
M.R.	3			-.40	.48	.56	-.07	-.43	.62
X_1	4				-.62	-.20	.46	.33	-.64
X_2	5					.29	-.34	-.69	.80
X_3	6						.20	-.28	.29
X_4	7							.30	-.47
X_5	8								-.75
X_6	9								

r is significant at 5% level of probability for 0.27 and 1 % level of probability for 0.35.

N = 50

TOTAL REGION

VARIABLE	NO.	2	3	4	5	6	7	8	9
S. I.	1	.59	-.23	.56	-.38	-.34	.55	.50	-.73
% Cover	2		-.23	.55	-.80	-.23	.36	.73	-.79
M.R.	3			-.36	.33	.46	-.03	-.26	.42
X_1	4				-.48	-.20	.36	.25	-.55
X_2	5					.10	-.24	-.55	.56
X_3	6						-.01	-.37	.44
X_4	7							.28	-.42
X_5	8								-.80
X_6	9								

r is significant at 5 % level of probability for 0.23 and 1 % level of probability for 0.30.

N = 75

APPENDIX XI

Coefficients of the principal and rotated components on 28 species from black spruce stands. Total region.

Components		Principal					Rotated				
Axes		Y_1	Y_2	Y_3	Y_4	Y_5	Y_1	Y_2	Y_3	Y_4	Y_5
Percent of total variance		25.7	14.6	7.3	6.2	4.4	Not calculated				
Strata	species										
Tree	BEp	.57	.10	-.16	-.23	.13	.26	.05	-.11	-.78	.07
	POt	.60	-.04	-.04	-.13	.32	.16	-.03	-.21	-.21	.32
Shrub	CHAc	-.65	-.33	.02	-.23	.33	-.85	.06	.17	.00	-.11
	DIl	-.33	.40	.47	-.21	-.12	-.03	.27	.77	.00	-.16
	KAa	-.67	-.30	-.03	-.12	.33	-.85	.08	.09	.04	-.01
	KAp	-.68	-.24	.21	-.10	-.15	-.58	.03	.30	.33	-.10
	LEg	.51	-.38	.35	-.00	-.02	.06	-.48	-.06	-.19	-.05
	SOa	.55	-.20	.03	-.23	.14	.11	-.17	-.05	-.75	-.00
	VA	-.26	.23	.73	-.08	-.04	-.03	.05	.84	.16	.11
Herb	ARn	.46	-.42	.24	.11	.20	.10	-.41	-.07	-.10	-.06
	ASm	.43	-.63	.13	.42	-.02	.04	-.87	-.08	-.08	.01
	CA	-.50	-.64	-.00	-.09	.06	-.68	-.20	-.13	.11	-.07
	CHh	-.37	-.27	-.08	-.35	-.56	-.28	.11	.05	.13	-.79
	COc	.50	-.22	.25	-.39	-.37	.17	-.16	.06	-.22	-.11
	LIb	.61	-.40	.18	-.24	-.15	.10	-.32	-.10	-.20	-.01
	MAc	.55	-.38	.23	-.32	-.02	.13	-.12	-.12	-.16	-.05
	MIn	.27	-.66	.03	.41	-.11	-.03	-.83	-.18	-.06	-.04
	PEp	.28	-.65	.13	.38	-.17	-.08	-.84	-.07	.05	.10
	SMt	-.58	-.45	-.18	.01	.07	-.61	-.04	-.31	.21	.04
	TRb	.54	-.41	.03	-.01	.20	.11	-.40	-.15	-.41	.09
	VAo	-.69	-.51	-.05	-.05	.17	-.86	-.07	-.04	.13	-.00
	VAr	-.11	.07	-.21	.48	-.29	.02	-.04	-.13	.04	-.06
Moss	Cs	.60	-.16	-.08	-.14	-.02	.36	-.07	-.07	.05	-.00
	CLA	-.20	.47	.49	.45	.08	.22	.14	.52	.10	.44
	Du	.30	.24	.21	-.13	.08	.24	.13	-.05	-.00	.14
	Hc	.35	.11	-.56	-.03	-.27	.38	-.15	-.26	-.24	-.41
	HYp	.55	.05	-.35	-.11	.16	.27	-.01	-.22	-.23	-.01
	SPH	-.74	-.43	-.13	-.23	-.13	-.71	.07	-.11	.20	-.33

APPENDIX XII Vectors, variances and loading components of 6 species groups and 5 selected species groups with regard to the black spruce association.

Regions		Total					Continental				
Vectors		Y_1	Y_2	Y_3	Y_4	Y_5	Y_1	Y_2	Y_3	Y_4	Y_5
Variances	Absolute	2.74	1.36	0.86	0.69	0.35	3.20	1.22	0.68	0.44	0.21
	%	45.7	22.7	14.3	11.5	5.8	55.0	20.3	11.2	7.3	3.5
Components		a_{1j}	a_{2j}	a_{3j}	a_{4j}	a_{5j}	a_{1j}	a_{2j}	a_{3j}	a_{4j}	a_{5j}
Observed variables	X_1	.67	.35	.18	- .63	.15	.76	.16	- .55	- .21	.19
	X_2	- .76	- .24	- .37	- .18	.45	- .89	.09	- .06	.26	.35
	X_3	- .51	.28	.76	.20	.23	- .34	.82	.28	- .35	.05
	X_4	.16	.96	- .30	.10	.06	.55	.69	- .08	.44	- .10
	X_5	.84	.01	- .15	.48	.26	.80	- .16	.52	.06	.19
	X_6	- .90	.48	- .17	.04	- .14	- .94	.01	- .10	.02	- .09
Variances	Absolute	2.85	0.87	0.71	0.45	0.12	3.01	1.07	0.62	0.29	.01
	%	57.0	17.3	14.3	8.9	2.5	60.2	21.5	12.4	5.8	0.1
Observed variables	X_1	.69	.41	- .54	.25	.11	.61	.70	- .36	- .07	.03
	X_2	- .77	.23	.32	.51	.04	- .79	.54	- .17	.23	- .03
	X_4	.56	.66	.46	- .20	.02	.63	.45	.63	.11	- .00
	X_5	.80	- .45	.32	.10	.22	.83	- .31	- .20	.42	.00
	X_6	- .91	.13	- .11	- .27	.25	- .97	.02	.16	.21	.05

Intensive management of most productive and most accessible forests will be more and more necessary in the province of Quebec. As this practice requires sufficient knowledge of forest ecosystems, the Research Service of the Quebec Department of Lands and Forests gives a great importance to the study of forest ecosystems and to the development of methods to define them more easily or more precisely.

SERVICE DE LA POLYCOPIE
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