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THE NUMERICAL ANALYSIS OF VEGETATION PLOTS IN DENALI NATIONAL PARK AND PRESERVE

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THE NUMERICAL ANALYSIS OF VEGETATION PLOTS IN DENALI NATIONAL PARK AND PRESERVE

A

THESIS

Presented to the Faculty of the

University of Alaska in partial fulfillment

of the Requirements for the Degree of

Master of Science

By

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Fairbanks, Alaska

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THE NUMERICAL ANALYSIS OF VEGETATION PLOTS IN DENALI

NATIONAL PARK AND PRESERVE

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DEDICATION

This thesis is dedicated to

JIM STELMOCK

who would understand.

There is no such thing as a problem without a gift for you in its hands. Jim reminded me of the appreciation, respect and joy for life that IS, but so easily lost in the perspective of a thesis problem.

Jim is the reason for this thesis BECOMING. Jim will always be a constant part of the respect, appreciation, gratitude and love I feel for the life processes in Denali National Park and Preserve.

What the caterpillar calls the end of the world, the master calls a butterfly.

ABSTRACT

The vegetation of Denali National Park and Preserve was sampled to develop baseline descriptive information on plant communities in the study area. Vegetation types and environmental relationships were identified and described objectively using a polythetic devisive cluster analysis (Twin Indicator Species Analysis) and an indirect ordination technique (Detrended Correspondence Analysis). The graphing of vegetation types and baseline environmental information on the X-Y ordination plane revealed that the composition and structure of the vegetation is related to a complex topographic exposure gradient. The major vegetation pattern is related to increasing climatic stress at higher altitudes.

In comparison with other studies in Alaska this study resulted in a high diversity of community types which was attributed to topographic heterogeneity, climatic stress and history of a variety of disturbing factors. The large number of previously undescribed mixtures appears to be associated with altitudinal limits of species, ecotones and sub-climax successional types.

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Dr. Frederick C. Dean, my committee chairman, deserves special recognition and thanks for his constant support, understanding, and perseverance.

I especially want to thank the numerous individuals who gave me positive support in many different ways through this problem.

INTRODUCTION

This thesis is part of a study conducted to provide reference information for a mapping project and to develop baseline descriptive information on plant communities in Denali National Park and Preserve. Remote sensing technology was used in the mapping of vegetation types. Dean (in preparation) and my sample plots provided a basis for the interpretation, calibration, and extrapolation of the reflectance data. Vegetation types were identified objectively from my sample plot data using cluster classification and ordination. The results provide additional descriptive information on Alaskan plant communities and were also compared to other studies in Alaska. The entire effort was closely correlated with the attempt being made at the time to develop a unified statewide system of vegetation classification.

Few quantitative analyses of interior Alaskan forests are available. Foote (1976) classified plant communities following fire in the taiga of interior Alaska, and Yarie (1980) classified the forest vegetation in the Porcupine River area of northeastern Alaska. Quantitative information on Alaskan alpine plant communities is also scarce. Palmer (1942) and Viereck (1962a and b; 1963) described alpine plant communities in the Alaska Range, but I know of no attempts to classify alpine tundra in interior Alaska using modern quantitative methods.

Since the primary purpose of my sampling was to provide reference data for interpreting Landsat spectral class information and to assist in calibrating the resultant mapping, my sample plots were chosen to represent a broad continuum of conditions from the complex terrain and vegetative cover types present on the study area. Both the north and south sides of the Alaska Range are represented, and cover types range from alpine skree to taiga.

STUDY AREA

The mapping project was initiated as a preliminary stage of a study to assess the influence of range-related factors on the decline of the Denali Caribou herd previously referred to as the McKinley Caribou herd.

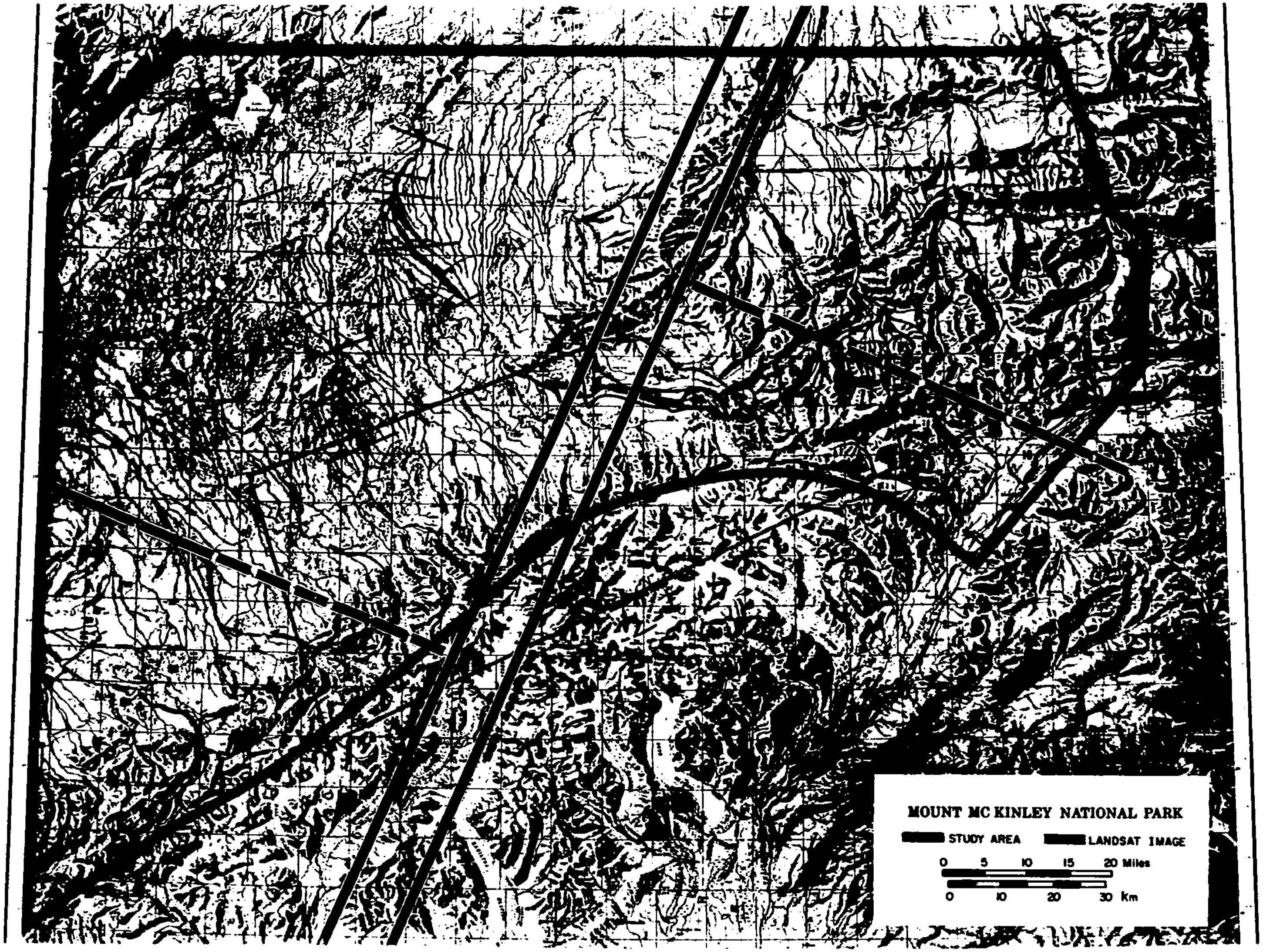
Boertje (1981) has modeled the factors controlling the energetic and nutritional status of the herd on a year round basis and another study is focusing on range productivity (Schultz, in preparation). Dean (in preparation) is providing a map of the plant communities of the historic and present day Denali Caribou range. My study area was related to the extent of this map and included most of the area within the boundaries of the old Mount McKinley National Park and a large portion of the surrounding region (Figure 1). The name of the area was changed by the Alaska National Interest Lands Conservation Act. The old name Mount McKinley National Park, will be used interchangeably with the new.

Climate

Denali National Park and Preserve and its surrounding region are located in two of the major climatic zones of Alaska. The two zones are separated by the Alaska Range which forms a barrier to the coastal winds that bring moisture from the Pacific Ocean and Gulf of Alaska. The

Figure 1. Topographic map of Denali National Park and Preserve Study area. The thick black line delimits the study area boundary. The east boundary is the Nenana River; the north boundary is the 64°N parallel west to Lake Minchumina (152°W); the west boundary is Lake Minchumina southwest to 154°W meridian, then south to the upper vegetation line on the north side of the Alaska Range; the south boundary is the upper vegetation line, then east and northeast to the Parks highway via the upper vegetation line and West Fork Glacier and River, then northeast along the highway to the Nenana River crossing.

The thick patterned line delimits Landsat image coverage. The dashed patterned line delimits edge overlap of two Landsat images flown on the same date. Thin dark lines (-) illustrate the stratification of the study area on the basis of physiography. Arrows (⟶) are the starting points and direction of the random grid transects used for vegetation sampling in 1977.


MOUNT MC KINLEY NATIONAL PARK
STUDY AREA
LANDSAT IMAGE
0 5 10 15 20 Miles
0 10 20 30 Km

climate north of the range is continental in character, warmer in summer and colder in winter than the area south of the range which is influenced by the ocean.

Few weather data exist for the study area. During the years 1925 to 1929 a weather station was maintained at Wonder Lake at an elevation of 610 m. Weather data have also been kept at Summit, an FAA station on the Alaska Railroad, on the south side of the Range just below regional treeline. Records are also available from Lake Minchumina and Talkeetna. Weather data for the park, reflecting a 30-year average, was obtained from recording devices at Park headquarters. The weather station at Park headquarters is located in a white spruce forest on a sheltered southeast exposure at an elevation of 1,000 m. Annual temperature extremes range from 32°C to -47°C at the Park headquarters' weather station. The average 24-hour temperature range during June through August is 22°C. Wider daily swings occur in winter.

Since there are many variables affecting local temperatures, the only generalization might be that temperature in the study area tends to decrease with elevation. Summit Station at 732 m has an average annual temperature of -3.6°C compared with Talkeetna's 1.9°C at 105 m.

Average precipitation at Park headquarters is approximately 381 mm. Snowfall is 1,923 mm. Winters have less precipitation than summers. November has the lowest monthly average at 8 mm, March has the winter high at 32 mm. The monthly averages for the three warm months show 73 mm for June, 96 mm for July and 59 mm for August. Average precipitation during May, June, July, August and September is 17, 49, 66, 71 and

39 mm, respectively (U.S. Department of Commerce, 1970). Although annual precipitation is nearly the same at all four stations, there is marked variation in the number of days on which rain occurs during June, July and August. Rain occurs on 21 days at McKinley and Lake Minchumina, on 36 days at Talkeetna and on 45 at Summit. In general, the study area is known for its cool wet summer weather. Summer precipitation generally comes as frequent light drizzles and showers due to surface heating during the day and the influence of the montainous terrain.

Snow drifts to 6 m or more at higher levels in the study area, but at Park headquarters the normal snowpack is 508 mm with a maximum at 1,118 mm. In the winter, storms from the south drop heavy snows on the main range. Both the Headquarters' weather station and the mountains just to the north are in a precipitation shadow, but the strong winds from the south are most prevalent in the main river valleys and at high elevations, blowing snow from exposed areas.

A general snow cover usually remains into late May or early June, and drifts in sheltered areas may last much later. Freezing temperatures may be experienced during any month.

Calm days are more characteristic of the summer and turbulence of the fall and winter. During the summer surface winds resulting from daily temperature fluctuations are prevalent and range from 8 to 24 $km \cdot h^{-1}$ (U.S. Department of Commerce, 1970). Cloud cover greater than 70% can be expected on about 40% of summer days.

Physiography

Denali National Park and Preserve covers in excess of 23,000 km^2 of interior Alaska. Physiographically the study area lies mainly in the Alaska Range section of the Alaska-Aleutian province of the Pacific Mountain system. Lowlands north of the Alaska Range lie in the Tanana-Kuskokwim lowland section of the Western Alaska province. Between these sections lie the northern foothills of the Alaska Range. The study area south of the Alaska Range is in the Cook Inlet-Susitna lowland section of the coastal trough province of the Pacific Mountain system (Wahrhaftig, 1965).

The Alaska Range consists of two and sometimes three parallel, rugged, glaciated mountain ridges with an altitude of 1,830 to 6,194 m in the eastern section of the park. The northern foothills (locally called the Outer Range) of the Alaska Range consist of a series of sub-parallel west-trending ridges with altitudes ranging between 610 and 2,400 m. Small glaciers are found in cirques over 1,500 m. Perennial snowline generally occurs between 2,130 and 2,440 m on the north flank of the range and is slightly higher on the south flank. The ridges are separated by long narrow valleys. Northward flowing rivers cut dendritic patterns roughly perpendicular to the ridges and valleys. West of the northern foothills lies a broad region of lowlands drained by the Tanana and Kuskokwim rivers with altitudes of 183 to about 488 m. Lowlands lie adjacent to the Alaska Range on the south with elevations to 914 m.

Geology

A detailed comprehensive summary of the geology of the study area has been made by Gilbert (1979). The Alaska Range is relatively young which in addition to the severe climate is a factor in the rapid erosion visible everywhere. Wahrhaftig (1965) described the internal structure of the Alaska Range as a synclinal complex with cretaceous rocks in its center and Paleozoic and Precambrian rocks on the flanks. Longitudinal faults, Denali being most significant, are approximately parallel to the range. The McKinley segment of the Denali fault is presently active and marked by small scarps, sag ponds, offset drainages, glacier-filled valleys and Holocene glacial deposits (Reed and Lamphere, 1974). Granite rocks intrude the Paleozoic and Mesozoic rocks of the range. Synclinal areas of Tertiary rocks lie in lowlands that parallel the range front. A thick conglomerate cover near the top of the Tertiary rock section forms ridges where dips are steeper than 20° and broad dissected plateaus where the conglomerate cover is flatlying. Much of the present topography is a result of erosion and removal of the weaker Tertiary rocks.

North of existing glaciers of the Alaska Range, morainal and glacial outwash deposits extend into the northern foothill belt and cover large areas of bedrock. Except for the widening of some valleys by past advances of the Alaska Range glaciers, the foothill section was never glaciated and consists of a series of low, flat-topped, east-trending ridges composed of crystalline schists and granitic intrusive rocks. Separating the ridges are rolling lowlands underlain by poorly consolidated Tertiary rocks. Superimposed across this topography are the braided glacial streams that arise on the north flank of the Alaska Range. Terraces along these streams illustrate the Quarternary uplift of the range. In the western section of the park, the Tanana-Kuskokwim lowland which is a broad depression filled by alluvial sediments lies to the north of the Alaska Range. This area will also be referred to as Tanana lowland for brevity. The numerous lakes and ponds that mark this landscape unit are apparently the result of thawing of permafrost.

South of the range, the Cook Inlet-Susitna lowland is characterized by ground moraine, drumlin fields, eskers and glacial outwash plains. Nearer to the Alaska Range the valleys are broad and flat-floored with valley walls illustrating evidence of glacial advances. Bedrock beneath the Cook Inlet-Susitna lowland is primarily poorly consolidated Tertiary rocks (coal-bearing) which are flat-lying or only slightly deformed.

Wahrhaftig (1958) has recognized 4 periods of glaciation in the eastern section of McKinley Park. Glacier ice apparently did not extend far from the range, although along the Nenana and McKinley Rivers the extent was greater.

Periglacial features such as discontinuous permafrost, thermokarst, solifluction lobes, and patterned ground are common within the park. Solifluction features and patterned ground are most conspicuous at higher elevations.

Soils

An exploratory soil survey has recently been completed in Alaska (USDA 1979) based on the taxonomic soil classification system used by the U.S. Soil Conservation Service (USDA 1975). This survey classified and mapped Alaskan soils according to order, suborder, and subgroup, with none being classified below the subgroup level. The soils in the study area have not been described in greater detail except for Viereck's (1962b) study on the glacial outwash of the Muldrow.

Two general soil toposequences can be recognized in the study area, one corresponding to flood plain microrelief and successional development, the other related to elevation on the slopes. On the Tanana-Kuskokwim lowland, the floodplain substrate ranges from well-drained, fresh alluvium (Cryofluvents) along the river to Pergelic Cryaquepts on stream terraces and Histic Pergelic Cryaquepts in depressions. The present river channels are in places bordered by poorly drained soils which were previously separated from the rivers by natural levees. Because the rivers have shifted their channels in the floodplain some well-drained levees are not adjacent to the streams and in some places are miles away.

Pergelic Cryaquepts are shallow soils of moderate to poor drainage with a relatively thin organic layer. These soils developed in silty material of variable thickness over very gravelly glacial drift. Most of the soils have a shallow permafrost table, but in some of the very gravelly well-drained soils permafrost is deep or absent. These soils may be saturated early in the season, but generally drain somewhat by midsummer. The wettest soils are the Histic Pergelic Cryaquepts of floodplain depressions. These are typical bog soils characterized by a thick accumulation of organic matter and a shallow active layer, although the actual soil depth (largely organic) may be several meters. Histic

Pergelic Cryaquepts generally develop in very gravelly glacial drift and colluvial material, although the depth of thaw may not reach the mineral horizon. Ice lenses and other surface irregularities such as mounds and cracks occur in the soils as a result of frost action. Such soils remain saturated and in some cases inundated throughout the growing season.

The elevational soil sequence is influenced considerably by slope and aspect with Pergelic Cryaquepts extending to higher elevations on north slopes than on south slopes and grading upward into Spodosols (Pergelic Cryorthods) and ultimately into shallow, stony soils or rocky barrens with little or no vegetation (rough mountainous land). Pergelic Cryorthods are characterized by shallow soil depth (less than 50 cm) and having a thin albic horizon over a reddish brown spodic horizon. The soils are very well-drained and do not retain enough moisture to develop perennial frost. Patterned ground due to frost action is common, particularly sorted features such as stripes or rings (USDA, 1979). The down-slope movement due to frost creep and solifluction disrupts and obscures soil morphology and the profile tends to be irregular and discontinuous.

Viereck (1962) described the soil toposequence and successional development on progressively older terraces of the McKinley River. He found no significant differences in the clay fraction in the successional sequence, but an increase in the silt fraction and a corresponding decrease in the sand fraction as the soil develops. Viereck suggested the increase of the two organic layers in the soil profile to be the most important aspect of soil formation in the chronosequence. He found a decrease in pH from 8.2 in the unaltered outwash to 4.4 at a depth of

5 cm in the climax tundra stand. An organic soil develops in the climax stand due to the slow decay resulting from the cold, waterlogged and acid conditions.

It is evident that soil frost phenomena have a significant effect on both soils and vegetation in the study area, which lies in a zone of discontinuous permafrost (Ferrians, 1965). Ridgecrests, hilltops, south-facing slopes, stream banks and freshly deposited alluvium are generally permafrost-free or with a deep active layer. North-facing slopes and lowlands are usually underlain by permafrost and have a shallow active layer.

The interactions of vegetation and permafrost are complex and generalizations difficult to make. A bibliographic collection of documents relating to the interrelationships between vegetation and permafrost has been compiled by Roberts-Pichette (1972). Viereck (1975) discusses the relationship of forest succession to soil development and the interaction of permafrost development on the Tanana River.

Viereck (1973b) discussed the effects of fire and flooding on permafrost levels in the Fairbanks area. Lakes resulting from the melting of perennially frozen ground (thaw lakes) are thought to be important sites for bog formation (Drury, 1956). The thawing of the ground ice can result from a disturbance of the insulative moss mat caused by fire, water action, a wind-felled tree, etc.

Polygonal ground, a surficial expression of permafrost presence and activity, was prevalent in the study area especially in the Tanana-Kuskokwim lowland and Cook Inlet-Susitna lowland regions.

Seasonal cycles of uneven freezing and thawing in frozen and unfrozen ground is manifested by a wide array of soil and vegetation features. These include patterned ground phenomena such as polygons, circles, nets, steps, and stripes which result from cracking, heaving and sorting of soil material (Washburn, 1973). These frost features are widespread in the study area at high elevations. On lower slopes and valley bottom sites, frost action is more likely to be in the form of frost wedging. Viereck (1965) discusses perenially frozen mounds (permafrost lenses) beneath individual white spruce trees growing in silty clay on a terrace of the McKinley River in the study area. The mound is created through expansion of the silty clay caused by the incorporation of water into the lens as thin layers of clear ice. Frequently the cyclic development and degeneration of soil frost features result in similar cycles of vegetation disturbance and succession (Hopkins and Sigafoos, 1950; Drury, 1956), often at a very small scale.

The upland soils of the study area exhibit various forms of mass wasting, such as frost creep and solifluction. Frost creep is the downslope movement of material through heaving and settling (Washburn, 1973), while solifluction is the term generally applied to the movement of saturated soil with or without the presence of frozen ground. Both processes (particularly solifluction) are most evident on south slopes, where temperature extremes contribute to their intensity. Well-developed solifluction lobes and fans are characteristic resultant landforms.

Hydrology

The glaciers produce braided streams with milky waters from glacial silt in suspension. Twenty or more intermingling channels may flow in river beds, some over 3 km wide below various glaciers. The most important glacial rivers in the study area include the Tonzona, Swift Fork, Herron, Foraker, McKinley, Toklat, Teklanika, and West Fork of the Chulitna. Clear streams fed primarily from snowmelt occur sporadically throughout the area. Because of glacial gouging and moraine formation many ponds and small lakes occur in the study area. Wonder Lake is the largest glacially-carved and moraine-dammed lake and is nearly 4.8 km long.

On terraces created by outwash streams and receding glaciers, vertical distance to the water table could be an important factor in the development of vegetation. When the surfaces of the terrace are first abandoned by the river, vertical distance to the water table may be only 1 or 2 m. Continued down-cutting of the river increases this depth within a few years. The water table therefore apparently drops below effective use by the plants before the vegetation has developed to any degree on the terrace surface.

The ground water regime is complicated by the presence of permafrost in the study area. Circulation of groundwater occurs below the permafrost, through unfrozen channels within the permafrost, and above the permafrost in regions where the water table overlies the upper surface (Hopkins *et al.*, 1955) of the permafrost.

The numerous lakes and bogs which occur throughout the study area, due to permafrost, are reservoirs for precipitation and snowmelt. The function of these lakes and bogs as discharge areas for ground water has recently been substantiated by Kane and Slaughter (1973).

Other Environmental Factors

Several studies of the vegetation in McKinley Park in relation to environmental factors have been published. Viereck's (1962b, 1966) exceptional studies near the terminal moraine of the Muldrow Glacier offer information concerning plant succession and soil development on glacial outwash. Drury (1956) detailed physiographic processes and active floodplain bog succession in the Tanana-Kuskokwim lowland north of the study area. Stelmock and Dean (1979) in a study of the effects of trampling, provided data on community composition and structure in shrub tundra vegetation near the East Fork of Toklat. Hansen (1951) reported on a few stands in the park in a general vegetation survey of western Alaska.

Shelton (1962) studied the vegetational zonation on Igloo and Cathedral Mountains in the eastern portion of Mt. McKinley Park. A survey of the major vegetational zonation in the eastern portion of McKinley Park is included in Glaser's Ph.D. thesis (1978). Glaser (1978) reported the vegetation of McKinley Park has a

> general altitudinal zonation. The five major vegetation zones and their approximate altitudinal limits are boreal forest (490 to 950 m), shrub tundra (600 to 1,100 m), Dryas heath (1,040 to 1,430 m), Dryas fell-field (1,430 to 1,520 m), and fell-field (1,520 to 1,980 m). Individual plants are rarely found at higher altitude. In the overlap between

> these types a complex mosaic is formed as a result of local variation in wind exposure, snow cover, permafrost, and fire history. Fire and permafrost exert a strong influence on vegetational pattern at lower altitudes whereas wind exposure and snow cover become paramount in importance at higher elevations.

From the Alaska Range east of the study area there is evidence that the glacier activities are similar to the rest of the world with a series of advances since 1600 followed by a rapid recession. Péwé (1951) used tree cores to date the recent moraines on the Black Rapids Glacier at 200 to 300 years old. Wahrhaftig (1958b) postulated from information on a recent advance of the Yanert Glacier that a "cold period reached its climax between 1820 and 1920 and is apparently now on the wane". Viereck (1962) estimated the oldest glacial outwash terrace from the Muldrow Glacier to be between 200 and 300 years old. A white spruce tree dated by me at the moraine terminus of the Herron Glacier was 151 years old, and a tree on the moraine of the Herron was dated at 123 years which correlated well with Péwé's (1951) and Viereck's (1962) estimates, allowing some time for the establishment of the spruce.

Alaskan bog successional schemes as presented by Drury (1956) suggest that changes in floodplain vegetation were not unidirectional but cyclic. Drury maintained that under the appropriate physiographic conditions any of the major floodplain communities (e.g., black spruce muskeg, floodplain white spruce mixed forest) could eventually become bogs.

The interior of Alaska, with its low precipitation and warm summer temperatures is one of the most fire-susceptible regions of the state. Most of the interior has been burned over within the past 200-250 years (Barney, 1971). Fire is one of the most important factors affecting taiga ecosystems. Between 1940 and 1969, the average annual burned-over area in Alaska was approximately 400,000 hectares. Conifer (primarily black spruce) vegetated 36% of the area burned; mixed conifer-broad-leafed forests, 14%; broad-leafed forests (aspen, birch, cottonwood), 2%; tree-less (tundra, bogs and grassland), 43%; and other, 5% (Viereck, 1975). Viereck (1975) states, "Fire may be a more important factor in the structure of some of our tundra and bog types than has been previously acknowledged".

Buskirk (1976) compiled information on 68 fires which burned a total of 100,000 acres within the boundaries of the study area from 1924 to 1976. Buskirk found fire occurrence in the study area had peaks in 1958-59 and 1968-69 which parallel statewide trends. Lightning was responsible for both the greatest number (63%) of fires and the largest area burned (74%) in the years from 1924 to 1976. Most lightning fires were located in the Tanana lowland at elevations below 610 m. Ninety-five percent of the total area burned and 82% of the total number of fires in the study area between 1924-1976 were at elevations of less than 610 m (Buskirk, 1976).

Hardy and Franks (1963), Barney (1969, 1971b) found for the period 1940-1969 the average annual burn for Alaska is approximately 400,000 hectares. Thirty percent of these fires were caused by lightning which was responsible for 78% of the acreage burned. The study area statistics on area burned by lightning-caused fires parallel Alaskan trends.

Lutz (1956) and Viereck (1973a) provide excellent reviews of the effects of fire on vegetation, soil, hydrology, and wildlife in the interior. Foote (1976) provided a monumental quantitative and qualitative study on plant communities following fire in the taiga of the interior. Viereck (1973b) and Brown *et al.*, (1969) present discussions of data concerning permafrost conditions after fire. A recent symposium edited by Slaughter *et al.* (1971) summarizes the status of fire research and management in Alaska and northern Canada.

Previous Botanical Investigations

Many botanists have collected vascular plants in McKinley Park (original boundaries before d(2) addition) but only a few have published lists of their collections (Mexia, 1929; Nelson, 1939; Scamman, 1940; Briggs, 1953; Gjaerevoll, 1958, 1963, 1967; Viereck, 1967). Persson and Weber (1958), Ando, Persson and Sherrard (1957), Persson and Gjaerevoll (1957), Persson and Weber (1958), Persson and Gjaerevoll (1961) and Shacklette (reported by Persson, 1963) have reported on their bryophyte collections in the park. Weber and Viereck (1967), Krog (1962) and Howard (1963) published lists on lichen collections.

An up-to-date flora for the park is currently unavailable, and many of the herbarium specimens are widely scattered over North America and Europe.

The western portion of the study area which was recently added to McKinley Park to become Denali Park and Preserve has never been visited by botanists who have reported their investigations. The Kantishna Mining District is the farthest west botanists have reported collecting.

Due to the lack of uniformity in approaches to naming vegetation units and describing vegetation in Alaska, correlation of information between different areas and workers was difficult. Viereck and Dyrness (1980) in response, have proposed a unified statewide system for classifying vegetation. It is a hierarchial system with five levels of resolution. At the most general level the system contains five formations: forest, tundra, shrubland, herbaceous vegetation and aquatic vegetation. Based on IBP recommendations (Fosberg, 1967), the classification is devised to be a "pure classification system", i.e., it is based as much as possible on the characteristics of the vegetation itself (Viereck and Dyrness, 1980).

Viereck and Dyrness also state that

> because only vegetation is classified, a logically consistent hierarchial system can be developed. Such a system should be as objective as possible. Our classification has been developed by aggregation, with (existing) plant communities as the basic elements. We started with known communities, grouping them into broader classes based on similarity of composition by species.

Viereck and Dyrness (1980) present an excellent discussion and bibliography of vegetation scientists who contributed to the classification of Alaskan vegetation.

Little information, few quantitative analyses and very few attempts to classify communities are available for the taiga vegetation and alpine plant communities of Alaska.

Hettinger and Janz (1974) developed a classification for the taiga of northeastern Alaska and Hanson (1953) classified taiga communities in northwestern Alaska. Palmer (1942) and Viereck (1962a, 1962b, 1963) described alpine plant communities in the Alaska Range. Anderson (1972) described alpine tundra at Eagle Summit in the Tanana Yukon upland.

METHODS

Two summers of field work (1976 and 1977) were spent sampling the study area. The total study area which includes most of the present park and much of the d(2) proposal was divided into (a) an area that could be sampled intensively on the ground and which was relatively accessible from the road and (b) the larger and more remote remaining area which would receive much less intensive sampling.

A total of 241 site points was studied during the summer of 1976 in the former area using the methods described below. At a majority of these site points two random 5-m radius plots were evaluated for a total of 391 plots analyzed in 1976. Two hundred twenty-five of these site points were located within 11.2 km of the Park road. Sixteen were located north of the Park boundary in the west end of the Park within 6.4 km of Moose Creek.

Two hundred fifty-one plots were studied the summer of 1977 in the latter more remote remaining area. Eleven plots were located north of the Stampede Trail along the Teklanika River. Forty-nine plots were located in a 3.2 km zone along the McKinley River. Thirty plots were located in a 3.2 km zone along the Muddy River (flowing from Lake Minchumina to the Kantishna River). Ninety-one plots were evaluated in a 3.2 km zone along the Foraker River. Forty-three plots were evaluated in the foothills west of the Park boundary and east of the Swift Fork River. Twenty-seven plots were evaluated in the Broad Pass area south of the Alaska Range.

The plots along the McKinley River, Muddy River and Foraker River were reached in the course of float trips down these rivers in July and August. During six days that the Alaska Department of Natural Resources was using a helicopter in the foothills west of the Park boundary and the Swift Fork River, that agency generously provided limited use of the aircraft. All other plots were reached on foot.

I collected all unknown vascular and nonvascular plant specimens from the plots and also a sample of known species to serve as vouchers. Dr. David Murray verified many of the vascular identifications. Mrs. Barbara Murray helped with the identification of the nonvascular species and verified many of the identifications. Some of the better specimens are on file at the University of Alaska Herbarium. The other specimens are located in the Alaska Cooperative Park Studies Unit storeroom until catalogued and filed.

Plot Selection Design

My sampling design was geared toward the mapping project, and a primary consideration in my sampling was to collect unbiased data in as many different terrain and vegetative cover types as accurately as possible within very tight logistic constraints. Therefore, my sample plots were to be selected from a broad continuum of complex terrain and vegetative cover types. Because of the great size of the study area, the diversity of vegetation and the range of vegetation from alpine skree to Interior Alaskan taiga and bog stands, a method of vegetation analysis was used that would allow fairly rapid survey and also permit the results from the different vegetation types to be comparable and statistically analyzable.

A basic objective in the mapping project and in my thesis is the delineation of community units to be understood in terms of the spatial and ecological relationships of plots and species to one another. This objective requires that sampling be done in a manner unprejudiced by assumptions about community units. The two methods of sampling used were site points (summer 1976) taken at random within an accessible area through the whole vegetation pattern and site points located systematically along grid transects (summer 1977) that had been randomized along environmental gradients. Random selection allows the extraction of vegetational information from the area as statistically as possible while grid sampling allows the vegetational information to be examined in a spatial context. I used both methods of sampling in an attempt to combine the practical properties of each. The randomized site points method was a more effective means of sampling the complex terrain accessible from the Park road area. The grid transects with systematic point locations were more effective in sampling the more remote remainder which was relatively inaccessible without prominent topographical features.

The sampling unit, a circular plot with 5 m radius was chosen as it was easier for one person to measure. Dividing the circle also made frequency/cover easier to estimate.

Site points for analysis during the summer of 1976 were selected as a stratified random sample taken without replacement in an arbitrarily defined "accessible" distance from the Park road. Site points were selected and plotted, using a coordinate system superimposed on U.S.G.S. topographical maps and a pair of random numbers generated by the computer. To ensure representative sampling of the accessible area, the area was stratified on the basis of physiography (Figure 1). The number of site points located within physiographic strata was proportional to the stratum area (number of square kilometers represented on the map). Random points that fell within lakes, streams, or marshes were included in the population of points; and no stand selection criteria were observed.

Field Methods - 1976

Field methods for the summer of 1976 involved locating these random site points on the ground by compass triangulation and topographical features. At each site point the vegetation type was characterized and two plots with radii of 5 m were randomly located within this type. In huge areas of uniform vegetation a 100 m square was visualized surrounding the site point; and the two plots, each 78.5 m^2, were randomly located within this square. Two coordinates were visualized through the sample area, and a pair of random numbers was obtained from a random number table to relegate the position of each 5-m-radius plot with respect to this grid. Positions of plots were located by pacing, the random number coordinates becoming the center of the plot, from which a tape measure was used to delimit the boundary. Photographs were taken of all plots. A total of 241 site points were visited with 391 plots located and analyzed in 1976.

Environmental Data

The significant environmental data collected for each plot was (1) elevation (from the U.S.G.S. topographic map); (2) aspect, using a compass; (3) slope gradient, using a clinometer; (4) exposure using the scale (refer to (a) in Table 1); (5) drainage characteristics, using the scale (b) in Table 1; (6) ground surface pattern characteristics, using the scale (c) in Table 1; (7) ground cover description; (8) soil description; (9) geological type coded using the scale (d) in Table 1; and (10) surficial geology coded using the scale (e) in Table 1. Unvegetated ground cover was described by percent of ground surface covered by humus, mineral soil, decaying wood, rock, water and charred litter. A soil core or small soil pit was excavated at the center of each plot and soil samples were taken when convenient. Samples from 38 plots were dried and weighed and bulk density calculated. The soil profile was described as depth in centimeters of the following: litter, partially decomposed organic, amorphous organic, organic mixed with mineral, mineral and roots.

Table 1. Scales used to describe environmental data in plot analysis.

a) 1 = ridgetop, 2 = upper half; 3 = mid-slope; 4 = lower half; 5 = valley.

b) 1 = well-drained; 2 = poorly drained wet; 3 = standing pools of water; 4 = running water through plot. Percent of plot covered with water and distance in meters to a standing body of water over 1 acre was noted.

c) 1 = stream valley; 2 = solifluction lakes; 3 = gravel bar; 4 = vegetated glacial til; 5 = frost boils/pits; 6 = hummocky; 7 = irregular surface topography and moisture; 8 = alternate high moisture runoff or dry stream beds; 9 = basin; 10 = snow accumulation. Community well-protected from wind and shaded from sun.

d) Geological type coded as follows: 1 = sedimentary; 2 = metasedimentary; 3 = volcanic; 4 = metavolcanic; 5 = basalt/gabbroic; 6 = granitic; 7 = metamorphic; 8 = schist/gneiss; 9 = glacial ice/snow; 0 = unknown.

e) Surficial geology coded as follows: 1 = glacial moraines; 2 = recent moraines; 3 = older moraines; 4 = glacial/fluvial (undifferentiated); 5 = glacial outwash; 6 = fluvial outwash; 7 = alluvial/colluvial (undiff.); 8 = alluvial; 9 = colluvial; 10 = lacustrine deposits, 11 = eolian deposits; 12 = bedrock; 00 = unknown. (These types were abstracted by me with help from S. W. Hackett from the following reports: Gilbert, 1977; Gilbert and Redman, 1975; Gilbert *et al.*, 1976; Hickman and Craddock, 1976; Reed and Nelson, 1977; Reed, 1961). See appendix for detailed definitions.

Natural and man-induced disturbances were noted. Percentage of fire-charred biomass within each vegetation stratum was listed. Type, evidence and percentage level of wildlife use was also noted.

Vegetation Data

The vegetation type for the plot was described using types developed for the study area by me within the basic structure of early drafts of the Interagency Vegetation Inventory and Classification for Alaska (Viereck and Dyrness, 1980). Vegetational stratification was delineated as follows:

1. Trees were divided into three height classes (A1, A2, A3).
2. Shrub and herbaceous species were arbitrarily divided into tall and low growing (shrub: B1, B2; herb: C1, C2).
3. Nonvascular species were listed as those occurring on soil or humus, on decaying wood and on rocks (D_h, D_{dw}, D_r).
4. Epiphytes were listed as those occurring on trees, shrubs and herbs (E_A, E_B, E_C).

Total stratum cover and total cover by layer within strata was recorded. Cover was estimated as the percent of projected ground cover occupied within the 5-m-radius plot. Vascular and nonvascular species were recorded and unknown species collected. For each species recorded, the following data were listed:

1. The strata in which the species occurred.
2. The cover abundance of the species based on the following modifications of the Domin-Krajina Scale (Benninghoff, 1966).

CODE	DESCRIPTION	COVER %
10	any number, with approximately complete cover	95-100
9	any number, with more than 3/4 but less than complete cover	75-95
8	any number, with 1/2-3/4 cover	50-75
7	any number, with 1/3-1/2 cover	33-50
6	very often, with 1/4-1/3 cover	25-33
5	common, with 1/10-1/4 cover	10-25
4	abundant, with 1/20-1/10 cover	5-10
3	scattered, with cover up to 1/20	1-5
2	very scattered with small cover and erratic occurrence	<1
1	solitary with insignificant cover	

3. The sociability or degree to which individuals of a species were clumped within the quadrat.
4. The mean height of the species in meters.
5. Other notes about the condition, vigor or growth form of the species.
6. Percent of species browsed by vertebrates or invertebrates.

The diameter of all trees in the plot was measured and increment cores taken in 113 treed plots. The diameter was measured at chest height and increment boring was done as close to the base of the tree as the borer and presence of solid wood would allow. The cores were placed in straws, and rings on the cores were counted in the laboratory with the use of a dissecting microscope. Seedlings of each tree species were counted and/or ground cover was estimated. The height and diameter of standing dead trees was recorded and down dead perentage cover estimated. These procedures are only semiquantitative but have sufficient accuracy and greater efficiency compared to more detailed measurements.

Methods - 1977 Field Season

Field efforts during the summer of 1977 were directed toward sampling the more remote remainder of the study area with priority given to accessible areas covered by available good quality infrared photography and LANDSAT images. I mapped and visually interpreted the infrared photo coverage and LANDSAT images for field use. Grid transects were transferred from inch to mile U.S.G.S. maps to photos and images to aid in locating transects in the field. To optimize accuracy, efficiency and accessibility in the remote areas visited, two rivers were selected for floating, and cross country transects originating near access points such as airstrips were chosen in foothill terrain suitable for hiking. Starting points for cross country transects and river system transects were randomly located and plotted using a coordinate system superimposed on inch to mile topographical maps, the particular points resulting from a pair of random numbers generated by the computer. To ensure representative sampling, the accessible area was stratified on the basis of physiography. The number of starting points located within the stratified areas was proportional to the number of square kilometers represented on the map. Transects were plotted using these starting points, with plots located every 800 m. Transects were plotted on compass bearings approximately perpendicular and/or parallel to environmental gradients. River system grid transects were plotted as follows: a transect was drawn on a compass bearing perpendicular to the river for 3.2 km; 3.2 km from the river (and the random starting point) a 90° turn was plotted and 1.6 km long transect drawn approximately parallel to the river; another 90° turn was plotted and a transect drawn back to the river parallel to the previous 3.2 km transect. Plots were located every 800 m the entire length of the grid transect.

Transect starting points were located in the field using compass triangulation and available topographical features. The initial plot was located by referring to a random number table and taking the random number of paces along the transect line. Subsequent plots were located every 800 m by counting paces. Available topographical features were referred to for verifying locations of plots.

Plot data were recorded as in summer 1976 but in only one 5-m-radius plot at each site point. Along the transect vegetation type changes were noted with locations of type changes recorded. Dominant vascular and nonvascular species were listed for each vegetation type with their associated percentage cover. Qualitative observations on ground surface pattern and other items of interest were also noted.

Therefore in addition to the semi-quantitative plot data analyzable with the 1976 data, boundaries between vegetation types can be located along the transect with qualitative observations concerning variability within these types.

DATA ANALYSIS

In addition to the statistical dilemmas involved in quantitative vegetation analysis, it was a challenge to discover efficient programs capable of performing the desired analysis and also implementable on the Honeywell computer at the University of Alaska that would accomplish the desired analysis of my entire huge data matrix. After much literature research on the statistical analyses currently in use in vegetation/ ecology, I discovered that Gauch (1979) of Cornell University had a package of programs that met my requirements.

Type and Quality of Available Data

The within- and between-plot variation is not addressed statistically because the actual number of variables equals the number of species. Problems arise in assessing statistically this variation even with a multivariate analysis of variance due to the large number of variables and the presence of many zeroes in the data matrix. I have addressed qualitatively the following data set properties which can have an important effect on cluster analysis and ordination: (1) relative discontinuity; (2) presence of outliers; (3) noise level and redundance, and (4) relationships.

Relative discontinuity refers to the extent which sample points form natural clusters or groups. An outlier is a sample of odd composition as compared to all other samples. Outliers in my data set are of two types:

1) plots in vegetation types of rare occurrence;

2) plots in disturbed areas.

As discussed in the Field Methods section the study area was randomly sampled within an accessible subarea as dictated by logistics and time. Within this accessible subarea, the area was stratified on the basis of physiography. The number of site points located within physiographic strata was proportional to the stratum area. Therefore vegetation types of rare occurrence have few plots. Due to the random sample design there was no objective stand selection nor homogeneous requirement. Plots were included from disturbed or unique areas as marshes, rocky crags, unstable slopes with isolated plants, and gravel bars with low vegetative cover.

Noise level refers to the magnitude of sample differences below which difference is considered uninteresting or undefined. Field data from 1976 included two replicate plots for many sites. The similarity of replicate samples is affected by the number of species, size of samples, accuracy of measurement (estimation of species abundance) and degree of patchiness in the distribution of species (with respect to the size scale of the samples). Usually replicate samples are 60% to 90% similar rather than 100% similar (Bray and Curtis, 1957; Moore, 1972; Janssen, 1975). This phenomena is referred to as noise.

Data Transformations and Distance Measures

The effect of data transformations on ordination results has been discussed by Noy-Meir *et al.* (1975) and Noy-Meir and Whittaker (1977, 1978), and these effects apply also to cluster analysis. Different transformations emphasize different aspects of the data so choices of transformation and distance measures can affect results as can choices between clustering methods. Standardizations and transformations of the data matrix have major effects upon similarity. Sample relativization (giving each species a maximum abundance of 100) or any other standardizing adjustment based on rows or columns of the data matrix alters many numbers in the data matrix when a single number is changed.

Different strategies of transformation, standardization and choice of distance measures were applied to the initial clustering effort. The strategies of transformation and standardization were: no transformation, square root, logarithm (of value plus 1, using base 10), octave scale, presence/absence and relativization of sample totals to 100 (see Gauch, 1979, for explanation). Sequential transformation combinations were applied as follows: relativization of sample totals to 100 followed by logarithm; relativization of sample totals to 100 followed by conversion to octave scale; relativization of sample totals to 100 followed by square root.

It is advantageous to cluster several times using differing transformations, standardizations and distance measures. Analyses done using different strategies are influenced to varying degrees by the dominant species, total abundance and number of species.

The dominant species have the greatest influence in analyses on quantitative data without transformation as their abundances are the largest numbers in the data matrix. The dominant and rare species have equal influence when the presence/absence transformation is used. This transformation gives the same value to all species present regardless of abundance.

The following sequence of transformations is arranged with respect to the degree of influence of dominant species (i.e., greatest influence of dominant species to equal influence by dominant and rare species respectfully): no transformation, square root, logarithm, octave scale, presence/absence.

If samples vary in their total abundance, samples with low species abundances may be clustered together regardless of different species composition. The standardization, relativization of sample total abundance to 100, would allow the samples with low and high species abundances to be more comparable.

The influence of dominant species is also affected by the choice of distance measure in the analysis. The two distance measures used were Euclidean Distance and Percentage Distance. The calculation of Percentage Distance begins with computation of percentage similarity. This similarity is subtracted from the similarity among replicate samples (internal association assumed to be the value 100 which is the similarity between the most similar samples) to convert it to a distance measure. Euclidean Distance involves squaring numbers and therefore weights dominants more heavily than Percentage Distance. The equations for distance measures between samples j and k are:

Euclidean Distance $ED_{jk} = \sum_{i=1}^{I} (D_{ij}-D_{ik})^2$

Percentage Distance PD_{jk} = Internal Association-Percentage Similarity

Percentage Similarity $PS_{jk} = \dfrac{200 \cdot \sum_{i=1}^{I} \min (D_{ij}, D_{ik})}{\sum_{i=1}^{I} (D_{ij} + D_{ik})}$

where the summations are over all species (I), D_{ij} and D_{ik} are the abundances of species i in samples j and k, Internal Association is the value 100 as explained above.

The objectives of my strategy of data analysis were to: (1) classify and characterize core groups of species and samples; (2) define and describe relationships between these core groups of samples and species and (3) define and describe relationships between gradients of plant community composition and environmental gradients.

Cluster Analysis and the Delineation of Core Groups of Samples and Species

Two different methods were used to classify and characterize core groups of samples and species: a rapid initial composite clustering and a polythetic divisive classification. These methods are briefly described below.

Clear introductions to the techniques of cluster analysis may be found in the works of Peilou (1977), Williams and Lance (1977), Sneath and Sokal (1973) and others. Whittaker (1962), Orloci (1978) and Goodall (1978) review clustering in phytosociological applications.

In the present study, rapid initial composite clustering (CC) was performed with CompClus; program CEP-30 of the Second Edition of the

Cornell Ecology Program Series (Gauch, 1979). In CC the species by samples data matrix is conceived as a multidimensional space in which samples are points and species abundances are axes. The user selects the number of sample points to be chosen at random as center points. Samples are clustered within a user-specified radius of these center points. Samples can be reassigned from small clusters (defined by having fewer than a user-specified number of members) into the nearest large cluster, provided that sample is within a user-specified radius. Composite clustering is similar to classification around variable centers, the clustering method in TABORD (Maarel *et al.*, 1978) and the method in Janssen (1975). The objective of CC and similar methods is within-cluster homogeneity.

Separate clustering efforts using CC were undertaken for each of the nine tactics of transformation and standardization combined with each of the two distance measures.

The second method used to classify and characterize core groups was a polythetic divisive clustering namely two-way indicator species analysis (TWISA). Two-way indicator species analysis was performed by TwInSpAn program CEP-41 of the Second Edition of the Cornell Ecology Program Series (Gauch, 1979).

The method of polythetic division used in TWISA is the repeated dichotomization of a primary ordination of the samples. The samples are ordinated by reciprocal averaging (Hill, 1973) on the basis of a weighted average of the abundances of species which occur in the samples. Species are classified by TWISA in the same way as the samples except the species classification is made on the basis of fidelity to core groups of samples and not on the basis of the raw abundance data as in the sample classification. The fidelity of species J to class IC is defined by the ratio:

$$\text{RAT (IC, J)} = \frac{\text{mean occurrence of J in class IC}}{\text{mean occurrence of J in individuals not in IC}}$$

The fidelity ratio is used to define the species' attributes. Species J has attribute F(IC,K) if RAT(IC,J) is greater than or equal to a defined limit.

In the species classification, both the species and their attributes are given differing weights, as follows:

1) extra weight for high fidelity
2) extra weight for commoner species
3) extra weight for membership in larger groups and in the higher levels of the hierarchy in the sample classification.

Dichotomies do not arise naturally, and species indifference and preferentiality are a matter of degree with a sharp natural distinction between the two often not found.

The steps of making a dichotomy used in TWISA may be summarized as follows:

1) Identify a direction of variation in the data by ordinating the samples by the method of reciprocal averaging (Hill, 1973).
2) Divide the ordination at its center of gravity to get a "first draft" dichotomy of the samples.
3) Identify differential species that are preferential to one side or the other of the first draft dichotomy.

4) Construct a refined ordination of samples using the differential species and their frequencies of attributes on the positive and negative sides of the dichotomy.

5) Divide the refined ordination of the samples at its center of gravity.

Definition and Description of Relationships Between the Core Groups of Samples and Species

There are both direct and indirect approaches to gradient analysis. Direct gradient analysis is a subjective technique by which samples are arranged and studied according to their position along some predetermined environmental gradient. The indirect techniques are more objective as samples are compared and arranged solely on the basis of differences in species composition (floristics). Any correspondence between this arrangement and actual environmental gradients is inferred and less susceptible to investigator bias.

Weighted averaging is a direct ordination technique since it relies on subjectively assigned species weights. Weighted averaging is also related to indirect techniques since the resulting sample ordination is based on species composition. This method was developed independently by Curtis and McIntosh (1951) and Whittaker (1956). The values assigned to the species reflect their assumed positions on a known environmental gradient. These values or weights, when combined with species abundance values determine the position of a sample along the ordination axis.

Principal components analysis (Goodall, 1954; Orloci, 1966) is a purely objective mathematical technique for transforming one set of variates (the original data and correlation matrices of species abundance) into a set of component variates which are orthogonal, linear functions of the original variates and whose total variation is equal to that of the original variates. Although principal components analysis has been shown to be mathematically superior to many other multivariate techniques (Orloci, 1966), its appropriateness to ecological studies has been questioned (Beals, 1973; Gauch *et al.*, 1977). Principal components analysis assumes that relationships between species and environmental factors are linear and monotonic. In reality most communities contain species which are responding in a curvilinear fashion. The bell-shaped or Gaussian form of species distributions along environmental gradients and the non-linear decrease of sample similarity with increasing sample separation contribute to this curvilinearity. Ordination techniques which assume nonlinearity are weighted averages, reciprocal averaging, detrended correspondence analysis, gaussian ordination, parametric mapping and multidimensional scaling (Austin, 1976).

Reciprocal averaging was developed by Hill (1973), who demonstrated its relationship to both the direct technique of weighted averaging as well as to principal components analysis. Reciprocal averaging is a weighted average ordination derived from species weights assigned according to a rough initial gradient. This is followed by successive approximations (recalibrations of sample scores based on species scores and vice versa) leading to a final, stable ordination of samples. Reciprocal averaging has also been shown to be an eigenvector technique which is computationally related to principal components analysis but better suited to dealing with nonmonotonic species response (Gauch *et al.*, 1977). It should also be emphasized that with reciprocal averaging of species and stand scores the final scores arrived at do not depend on the initial scores assigned. The initial scores affect only the number of approximations needed to arrive at the solution. The reciprocal averaging is a "dual ordination of species and samples, with neither paramount and with the ordination expressing an optimal correspondence of species and sample scores" (Gauch *et al.*, 1977). Gauch, Whittaker and Wentworth (1979) tested reciprocal averaging using simulated community gradients and varied data set properties. The data set properties varied were beta diversity (floristic heterogeneity), sample errors or noise, number and importance of gradients, relative discontinuity, presence of outliers, variability in sample equitability and species amplitude. Reciprocal averaging produced results more consistent with field observations than principal components analysis. Gauch *et al.* (1977) point out that with reciprocal averaging the second axis and sometimes higher axes tend to be dependent on the first axis (known as the arch effect). This also occurs with principal components analysis and non-metric multidimensional scaling.

Detrended correspondence analysis (DCA) is an improved version of reciprocal averaging that demands there be no systematic relationship between the higher axes and the first. This reduces the distortion of the higher axes. Detrended correspondence analysis also shows improvement in dealing with outliers in the data set (Hill, 1979). Like reciprocal averaging DCA is a weighted average ordination affected by successive approximations (sample scores are a weighted average of the scores of the species which occur in it and vice versa). Detrended correspondence analysis differs from reciprocal averaging by breaking the ordination axis into a series of strips, then ordinating within each strip. This tends to equalize the species' variance along each axis. Axis length is expressed as standard deviations of species response. A sample ordination of four standard deviations means that species occurring at one end of the gradient are almost completely absent at the other end and vice versa. Technical details are given by Hill (1979).

Gauch (1979) has tested DCA on numerous sets of ecological and simulated community data in which he varied a number of data set characteristics. Detrended correspondence analysis produced more ecologically interpretable ordination axes when compared to reciprocal averaging, multidimensional scaling and principal components analysis.

Gauch *et al.* (1981) applied several nonmetric multidimensional scaling programs to simulated and real plant community data to test their effectiveness in comparison to reciprocal averaging and detrended correspondence analysis. Detrended correspondence analysis gave more realistic results than reciprocal averaging and nonmetric ordination and requires little computer time and storage. Variation of the sample set (beta) diversity, noise and dimensionality of data set did not alter the superiority of the results of detrended correspondence analysis.

Two-way indicator species analysis was used to exhibit the relationship between the species and samples. The TWISA classification was useful in providing a logical framework with which to describe variation in floristic composition. Since the basic strategy in TWISA is the division of the first axis of a reciprocal averaging ordination the structure of the classification will exhibit ecologically meaningful relationships between the core groups.

The ordination technique used to suggest relationships between sample core groups and species core groups was detrended correspondence analysis (DeCorAna; program CEP-40 of the Second Edition of the Cornell Ecology Program Series; Gauch, 1979).

RESULTS AND DISCUSSION

Qualitative Assessment of Data Set Characteristics and Classification Results

The program CompClus was used for the initial clustering of data including all plots and species. Tree and shrub species were treated uniquely by strata if individuals of the same species were present in different strata (i.e., *Picea glauca* in A1 strata with associated cover/abundance value was treated uniquely as opposed to additively with *Picea glauca* in A2 strata). There was marginal consistency, thus low utility in composition of clusters when applying the following strategies with CC:

1. The same data transformation/standardization and distance measure, with varied random number initialization.
2. The same data transformation/standardization and distance measure, with different cluster radius.

3. Different combinations of data transformations/standardizations and distance measures.

These strategies illustrated the following data set characteristics when the complete data set was analyzed with tree and shrub species treated uniquely by different strata:

1. The data show a nearly continuous structure with marginal natural clustering exhibited.
2. The data set is very noisy (i.e., replicate samples show much less than 100% similarity).
3. The data set is very hetereogeneous.
4. Cluster composition was based on the proportionately higher abundances of herb and nonvascular species as opposed to the abundance of tree and shrub species. The influence by herb and nonvascular species also resulted in poor consistency between cluster composition and the subjective classification of plots. The herb and nonvascular strata exhibited greater patchiness in the distribution of species with respect to the size of the samples and distance between samples than the tree and shrub species. The subjective classification was based on a more general pattern than the CC classification (tree and shrub species treated uniquely by different strata).
5. The replicate samples showed less similarity as compared to analysis done with no unique treatment for different strata. Similarity was assessed by comparing the distances between 100 random pairs of replicate samples using different techniques in the analysis. This

was again due to the influence of the higher abundance of herb and nonvascular species on the analysis. These species exhibited finer patterns than the tree and shrub species and replicate similarity was influenced by scale of pattern. In addition, the total number of tree data units was a small proportion of the whole as compared to the nontree data. The similarity of replicate samples is also affected by the number of species (651 with this analysis, 588 with no unique species treatment for different strata), size of the samples and accuracy of measurement of species abundance/cover estimations.

Composite clustering was then applied to the entire data matrix, but the analysis was done with no unique treatment for individuals of different strata. Random number initialization, cluster radius, transformations/standardizations and distance measures were variously combined as in the previous CC analysis. The most consistent and useful results were obtained with percentage distance used as the distance measure (in terms of natural clusters as subjectively classified being recovered and replicate samples showing greater similarity). These better results obtained than when using Euclidean distance were consistent when using different transformations/standardizations. Euclidean distance involves squaring the abundance/cover numbers and therefore dominant species have a greater influence on the analysis than with percentage distance. (Whenever dominant species is used in this thesis, I am referring to the species with the largest Domin-Krajina abundance/cover value.) With percentage distance used as the distance measure the four transformation/standardization tactics yielded consistent and useful results. The tactics listed in decreasing order of success of recovering natural consistent clusters and of similarity between replicate samples are: no transformation; relativization of sample totals to 100 followed by square root transformation; relativization of sample totals to 100 followed by octave scale.

Euclidean distance and various transformation/standardization combinations produced results differing in utility and interpretability. The following sequence of transformations/standardizations yielded results in decreasing order of utility: relativization of sample totals to 100 followed by log transformation; relativization of sample totals to 100 followed by square root transformations, relativization of sample totals to 100 followed by octave scale.

Varying these tactics of distance measure and transformation/ standardization combination in the analysis of the entire data matrix illustrates the following phenomena:

1. The data set is of intermediate discontinuity, being more continuous than neatly clustered. With a naturally clustered data set, CC can give repeatedly the same number of clusters and the same members in each cluster regardless of the random number used to initialize its random number generator or the transformation/standardization and distance measure used. With my data set, changes in the random number initialization, distance measures and modifications of the data matrix by different transformations/standardizations resulted

in changes in the number of clusters formed and in the members of each cluster.

2. The data set is very heterogeneous (high beta diversity) containing primarily qualitative information. This statement is justified by the fact that the results of the analysis are greatly affected when using different transformations/standardizations. My samples have highly variable total abundances (black spruce stand as compared to skree slope) and number of species. Many species are ubiquitous with wide ecological tolerances.
3. The analysis illustrated that there was a minority of plots which naturally clustered (as determined by consistency of cluster membership), but there is no natural number of clusters in the data set.

Composite clustering was then performed with no unique treatment for individuals of different strata, but the data matrix was divided on the basis of presence of a treed strata.

Percentage distance (PD) was the distance measure used because as explained with previous results PD gave more consistent discrimination. Based on varying strategies, the following qualitative comparative and characteristic statements can be made:

1. The treed data set is more neatly clustered, as the clusters had a smaller mean diameter than the nontreed data set.
2. The nontreed data set has a higher noise level and greater beta diversity than the treed data set. This is possibly due to the greater amount of patchiness in the distribution of nontreed species

(with respect to the size scale of the samples), greater number of samples of odd composition (outliers) in the nontreed data set and greater amount of variation in total abundance in the nontreed samples.

Classification of Core Groups

Initially TWISA was applied to the entire data matrix. Examination of results from TWISA indicated that outlying sample plots were distorting the polythetic divisive cluster analysis, and the plot groupings tended to be too broad and general in composition to be meaningful. DCA was also applied to the entire data matrix to confirm the cluster analysis results, and to aid in identifying outliers.

Two dimensional graphing of ordination results revealed the presence of outliers which appeared at the end of the ordination axis with all the other sample plots compressed at the other end.

Detrended Correspondence Analysis of the entire data matrix resulted in gradients that were too long and diverse with disjunctions and partial disjunctions. Detrended Correspondence Analysis and in certain cases also TWISA perform better on continuous data sets as opposed to disjunct data sets. Complete disjunction means that a vertical and horizontal line can be drawn through the data matrix dividing it into four submatrices, such that two submatrices are entirely zeroes and have no species composition in common. Partial disjunction refers to the situation where a few species are held in common in what would otherwise be entirely disjunct groups of samples. With partial disjunction the division between groups is arbitrary, and any of several possible divisions may give better ordination results than no division at all. Divisions of the data into subsets are subjective because outliers come in degrees and disjunction can be partial yet fairly strong.

The data set was divided to obtain continuous subsets of data with manageable diversity. Based on results from CC, DCA and TWISA and subjective plot classification using the Provisional Classification Framework for Alaskan Vegetation (Viereck and Dyrness, 1978) the data matrix was divided and outlying plots deleted in stages of "successive refinement". Several of the deleted samples were considered to be representative of either common, but extreme, situations or rare situations.

Two dangers in the "successive refinement" method are that (1) the investigator's interest or prejudice will concentrate the data analysis in a certain direction and (2) getting lost in details. The success of results usually cannot be assessed by statistical tests. The test of a descriptive application of classification and ordination is that it describes the vegetation effectively and permits its interpretation (Greig-Smith, 1971). Two-way Indicator Species Analysis and DCA were applied to the data in four stages of successive refinement as follows:

1. Entire data matrix
2. Two data matrices-divided on the basis of the presence of tree stratum.
3. Four data matrices-divided on the basis of the Provisional Classification Framework for Alaskan Vegetation (Viereck and Dyrness, 1978).

a. Coniferous forest data

b. Deciduous and mixed deciduous coniferous forest data

c. Low and tall shrub data

d. Dwarf shrub and shrub tundra data

4. Eight data matrices-based on the first major division of the TWISA of stage 3 groupings

a. Black spruce coniferous forest data

b. White spruce coniferous forest data

c. Balsam poplar mixed forest

d. Paper birch mixed forest

e. Alder/willow mixed shrub

f. Dwarf birch/willow mixed shrub

g. Mat and cushion tundra

h. Shrub tundra

These stages resulted from this investigator's objective of correlating the Denali National Park and preserve community types identified by cluster analysis with plant communities described by previous studies of Alaskan vegetation.

The first three stages were arbitrary physiognomic divisions designed to produce a description of the vegetation comparable to other Alaskan work. Composite Clustering, TWISA and DCA illustrated gradations between the groupings. These groups are also not clearly separated in reality. Dominant understory species in *Picea* stands have a wide ecological amplitude and extend onto tundra as well. *Picea* is of little importance in determining community structure and composition when compared to shrub species. The transition from forested to unforested is more a question of density rather than canopy coverage, with outlying individual *Picea* occurring in a variety of shrub communities. Trees, especially seedlings, are often present in plots classified as shrubland or tundra.

Stage four was based on the major dichotomy of the TWISA of stage three, and the groupings are based on floristic characteristics. Mat and cushion tundra and shrub tundra were distinguished by TWISA on the basis of floristics even though they are also physiognomic categories. The distinction between shrubland and shrub tundra is also poorly defined. Shrub tundra as used here refers to tundra communities dominated by ericaceous shrubs and polsters of shrubs as *Betula nana* and various species of *Salix*. Mat and cushion tundra is that dominated by spreading prostrate and cushion forms. Mat and cushion tundra may be either closed or open and in extreme situations plant cover is restricted to shelter or stable microsites on rock outcrops and talus slopes.

The plot groupings and results of TWISA at stage three were selected as most effective on the following basis:

1. field experience,
2. subjective grouping by assigned types developed for the study area by me within the basic structure of the Provisional Classification Framework for Alaskan Vegetation (PAVC) (Viereck and Dyrness, 1976),
3. ordination results,
4. the degree of correlation of Denali National Park and preserve community types with plant communities described by other studies of Alaskan vegetation.

The dendrograms constructed on the basis of TWISA clustering of the four data matrices at stage three are presented in Figures 2-5.

Two-way Indicator Species Analysis constructs the classification by identification of differential species. A small number of the most strongly differential species are termed indicator species and can be used as criteria for re-identification of the core groups. These differential species have clear ecological preferences so that their presence could be used to identify particular environmental conditions.

The indicator species which characterize the dichotomies are listed on the diagram. The indicators are listed in an approximate order of effectiveness in differentiating between the groups of the dichotomy. Technically the effectiveness of indicators is measured by the absolute value of the preference index as defined in the Data Analysis Methods section. Indicators have associated negative and positive signs depending on the likelihood of occurrence in the top (-) or bottom (+) of the dichotomy. The core groups of plots have identifying alphanumeric notations which will be used throughout the thesis. The listing of plots for each core group is in Appendix IV. A floristic key for re-identification of the groups in the classification (and possibly for the classification of samples not used in the analysis) is realized based on the use of these indicator species and the use of the dendrogram as a dichotomous key. Since the initial breakdown was based on physiognomic criteria, the floristic classification would be within level I of the preliminary classification system for vegetation of Alaska (Viereck and Dyrness, 1980).

Figure 2. Dendrogram constructed by TWISA through identification of differential species that are preferential to the top (-) or bottom (+) side of the dichotomy of plots. The codes C1 to C15 refer to the coniferous forest core groups which are floristically summarized in Table 2.

Appendix III is a list of plots in sequential arrangement by core groups as diagramed in Figure 2. Indicator species which characterize the dichotomies are listed in an approximate order of effectiveness in differentiating between the groups of the dichotomy. The abbreviations for the species are enumerated in Appendix IV. The analysis was based on 233 plots and 348 species.


Conifer
C 1
C 2
C 3
C 4
C 5
C 6
C 7
CLAD SPP(-)
CETR ISL(-)
ANDR POL(-)
EMPE NIG(-)
VACC ULI(-)
CARE BIG(-)
CHAM CAL(+)
CLAD THA(+)
RUBU CHA(+)
OXYO MIC(+)
LARI LAR(+)
TOME NIT(+)
HYLO SPL(+)
LEDU DEC(-)
LEDU GRO(+)
RUBU CHA(-)
BETU GLA(+)
OXYO MIC(-)
LARI LAR(-)
LEDU GRO(+)
EMPE NIG(-)
VACC ULI(-)
CARE BIG(-)
LARI LAR(+)
CLAD RAN(+)
RUBU CHA(-)
LEDU GRO(+)
ALNU CRI(-)
NEPH ART(+)
STER SPP(+)
LEDU GRO(+)
NEPH ART(-)
EQUI SYL(-)
ARCT RUB(+)
PICE MAR(-)
PICE GLA(+)
SPHA SPP(-)
CLAD RAN(-)
LARI LAR(-
CETR PIN(+)
PICE MAR(-)
PICE GLA(+)
LEDU GRO(-)
SPHA SPP(-)
LARI LAR(-)
EQUI SYL(-)
CETR SPP(-)
GRAM SPP(+)
PELT SPP(-)
PICE SPP(+)
(cont.)

Figure 2. Continued.

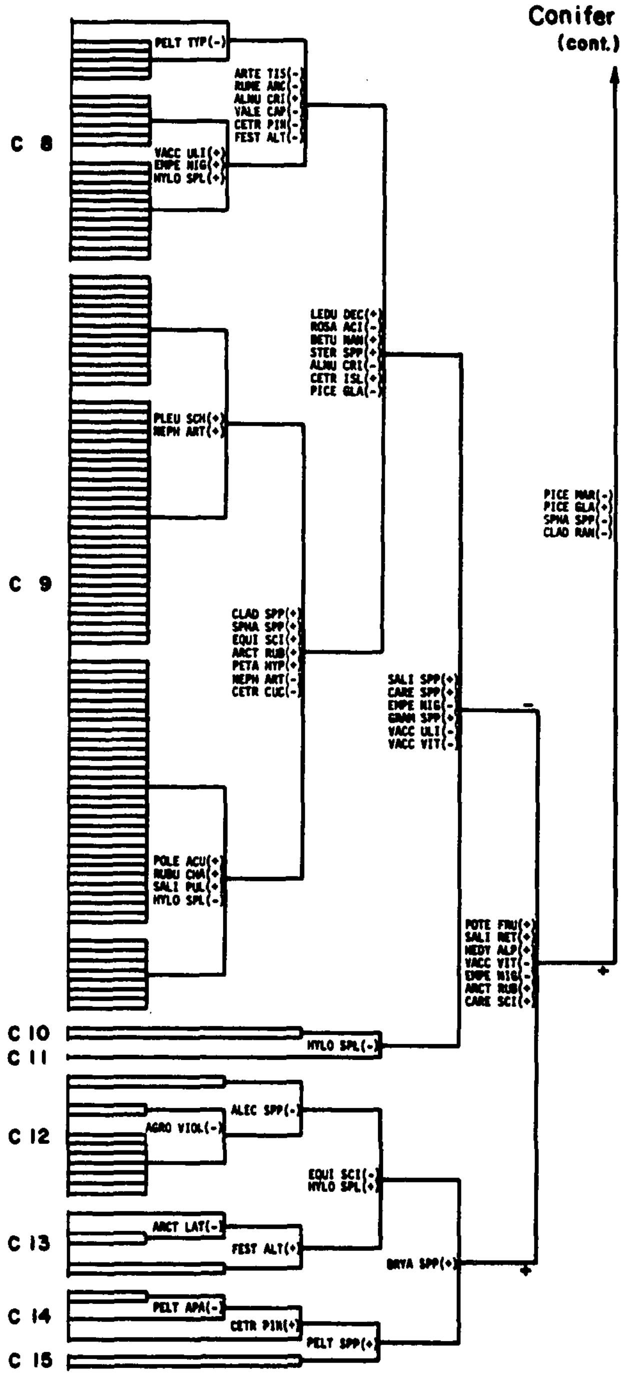


Figure 3. Dendrogram constructed by TWISA through identification of differential species that are preferential to the top (-) or bottom (+) side of the dichotomy of plots. The codes M1 to M14 refer to the deciduous and mixed deciduous-coniferous forest core groups which are floristically summarized in Table 2.

Appendix III is a list of plots in sequential arrangement by core groups as diagramed in Figure 3. Indicator species which characterize the dichotomies are listed in an approximate order of effectiveness in differentiating between the groups of the dichotomy. The abbreviations for the species are enumerated in Appendix IV. The analysis was based on 80 plots and 263 species.

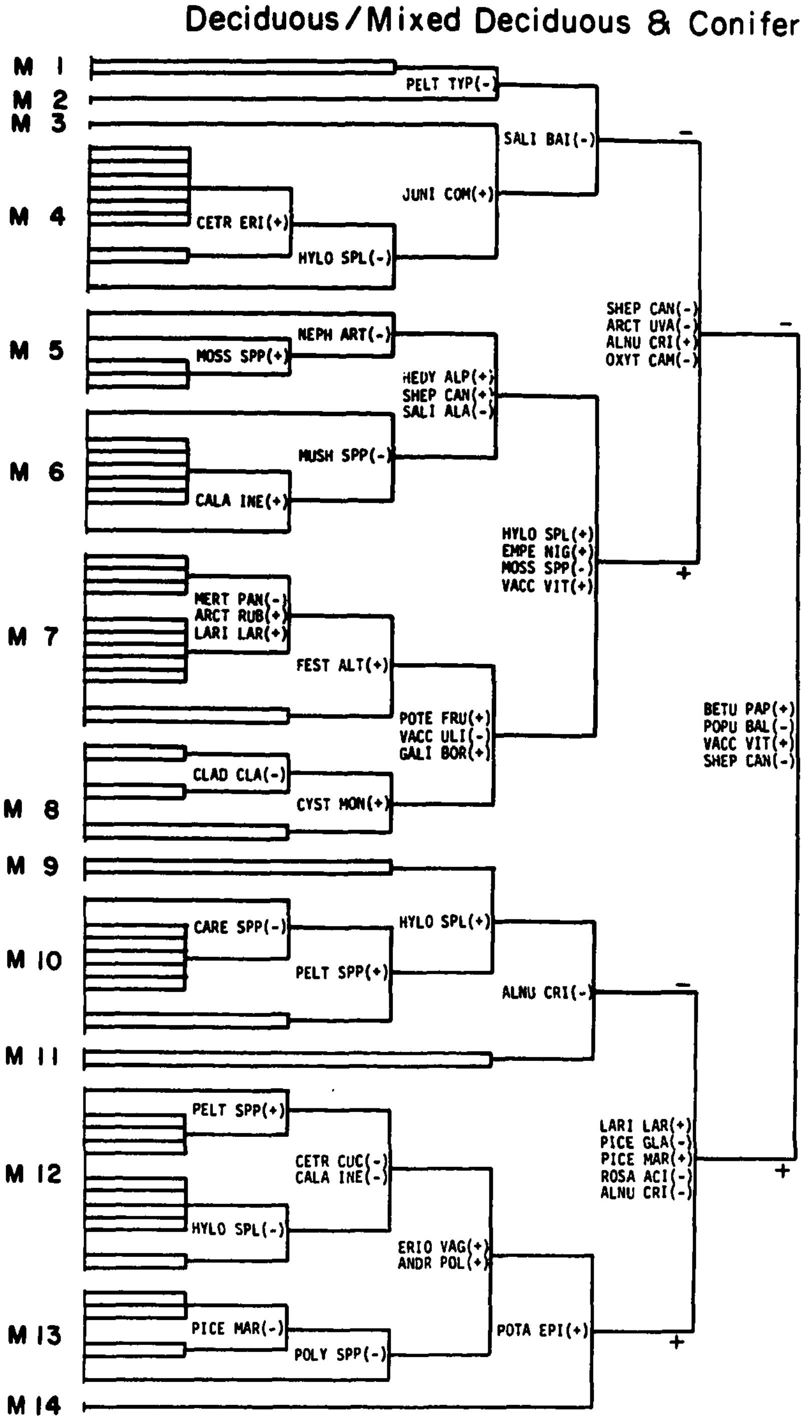

Deciduous/Mixed Deciduous & Conifer
M 1
M 2
M 3
M 4
M 5
M 6
M 7
M 8
M 9
M 10
M 11
M 12
M 13
M 14
PELT TYP(-)
SALI BAI(-)
JUNI COM(+)
CETR ERI(+)
HYLO SPL(-)
SHEP CAN(-) ARCT UVA(-) ALNU CRI(+) OXYT CAM(-)
NEPH ART(-)
MOSS SPP(+)
HEDY ALP(+) SHEP CAN(+) SALI ALA(-)
MUSH SPP(-)
CALA INE(+)
HYLO SPL(+) EMPE NIG(+) MOSS SPP(-) VACC VIT(+)
MERT PAN(-) ARCT RUB(+) LARI LAR(+)
FEST ALT(+)
POTE FRU(+) VACC ULI(-) GALI BOR(+)
BETU PAP(+) POPU BAL(-) VACC VIT(+) SHEP CAN(-)
CLAD CLA(-)
CYST MON(+)
CARE SPP(-)
HYLO SPL(+)
PELT SPP(+)
ALNU CRI(-)
PELT SPP(+)
CETR CUC(-) CALA INE(-)
LARI LAR(+) PICE GLA(-) PICE MAR(+) ROSA ACI(-) ALNU CRI(-)
HYLO SPL(-)
ERIO VAG(+) ANDR POL(+)
PICE MAR(-)
POLY SPP(-)
POTA EPI(+)

Figure 4. Dendrogram constructed by TWISA through identification of differential species that are preferential to the top (-) or bottom (+) side of the dichotomy of plots. The codes S1 to S16 refer to the shrubland core groups which are floristically summarized in Table 2.

Appendix III is a list of plots in sequential arrangement by core groups as diagramed in Figure 4. Indicator species which characterize the dichotomies are listed in an approximate order of effectiveness in differentiating between the groups of the dichotomy. The abbreviations for the species are enumerated in Appendix IV. The analysis was based on 96 plots and 344 species.

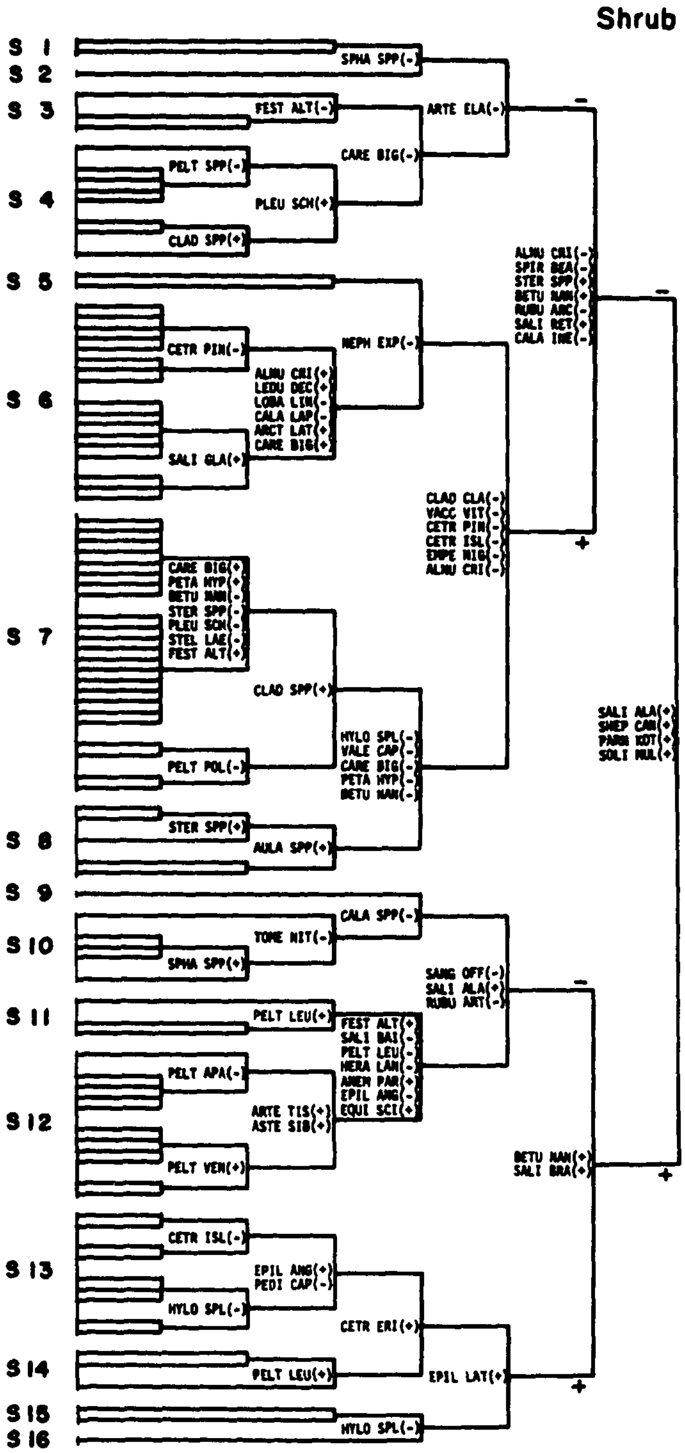
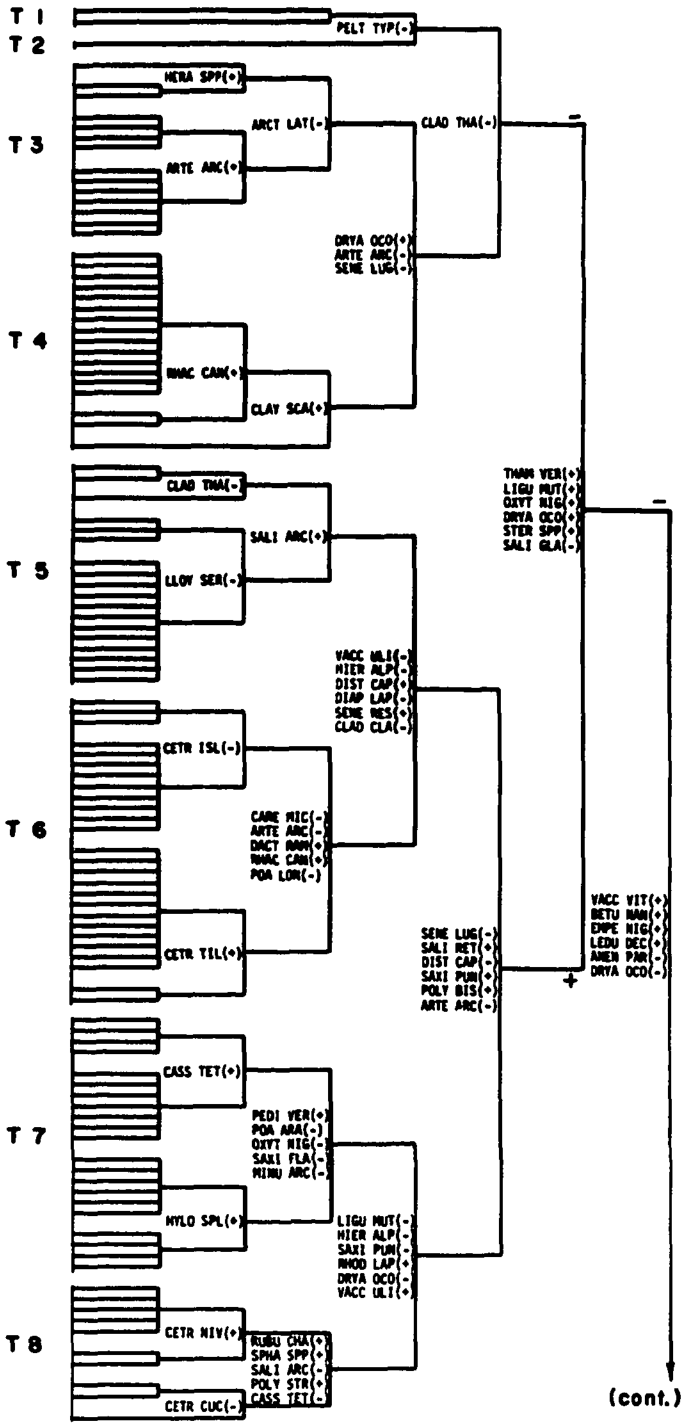

Shrub
S 1
S 2
S 3
S 4
S 5
S 6
S 7
S 8
S 9
S 10
S 11
S 12
S 13
S 14
S 15
S 16
SPHA SPP(-)
FEST ALT(-)
ARTE ELA(-)
CARE BIG(-)
PELT SPP(-)
PLEU SCH(+)
CLAD SPP(+)
NEPH EXP(-)
CETR PIN(-)
SALI GLA(+)
STER SPP(+)
AULA SPP(+)
PELT POL(-)
CLAD SPP(+)
CALA SPP(-)
TOME NIT(-)
SPHA SPP(+)
PELT LEU(+)
PELT APA(-)
PELT VEN(+)
CETR ISL(-)
HYLO SPL(-)
CETR ERI(+)
PELT LEU(+)
EPIL LAT(+)
HYLO SPL(-)

Figure 5. Dendrogram constructed by TWISA through identification of differential species that are preferential to the top (-) or bottom (+) side of the dichotomy of plots. The codes T1 to T14 refer to the Tundra core groups which are floristically summarized in Table 2.

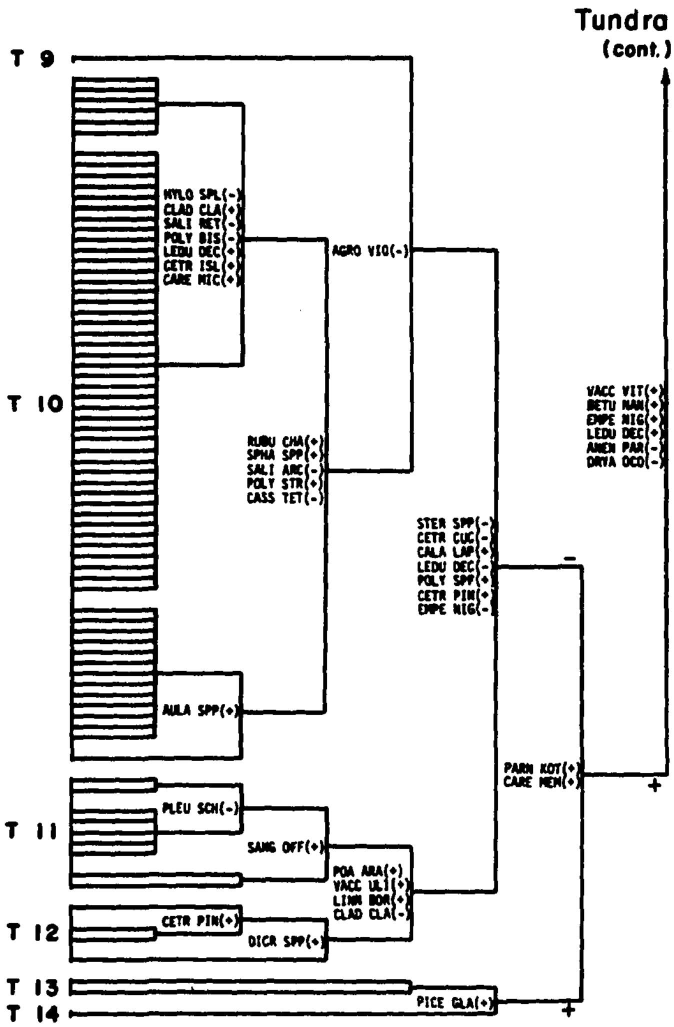
Appendix III is a list of plots in sequential arrangement by core groups as diagramed in Figure 5. Indicator species which characterize the dichotomies are listed in an approximate order of effectiveness in differentiating between the groups of the dichotomy. The abbreviations for the species are enumerated in Appendix IV. The analysis was based on 183 plots and 404 species.

Tundra


T 1
T 2
PELT TYP(-)
HERA SPP(+)
ARCT LAT(-)
CLAD THA(-)
T 3
ARTE ARC(+)
DRYA OCO(+)
ARTE ARC(-)
SENE LUG(-)
T 4
RHAC CAN(+)
CLAY SCA(+)
CLAD THA(-)
SALI ARC(+)
T 5
LLOY SER(-)
THAM VER(+)
LIGU MUT(+)
OXYT NIG(+)
DRYA OCO(+)
STER SPP(+)
SALI GLA(-)
VACC ULI(-)
HIER ALP(-)
DIST CAP(+)
DIAP LAP(-)
SENE RES(+)
CLAD CLA(-)
CETR ISL(-)
T 6
CARE MIC(-)
ARTE ARC(-)
DACT RAM(+)
RHAC CAN(+)
POA LON(-)
CETR TIL(+)
SENE LUG(-)
SALI RET(+)
DIST CAP(-)
SAXI PUN(+)
POLY BIS(+)
ARTE ARC(-)
VACC VIT(+)
BETU NAN(+)
EMPE NIG(+)
LEDU DEC(+)
ANEM PAR(-)
DRYA OCO(-)
CASS TET(+)
PEDI VER(+)
POA ARA(-)
OXYT NIG(-)
SAXI FLA(-)
MINU ARC(-)
T 7
HYLO SPL(+)
LIGU MUT(-)
HIER ALP(-)
SAXI PUN(-)
RHOD LAP(+)
DRYA OCO(-)
VACC ULI(+)
CETR NIV(+)
T 8
RUBU CHA(+)
SPHA SPP(+)
SALI ARC(-)
POLY STR(+)
CASS TET(-)
CETR CUC(-)

(cont.)

Figure 5. Continued.



The classification presented in Table 2 resulted from TWISA. The groups are defined by dominant or codominant species and species with high indicator value. Where several species of a particular type occur together in approximately equal proportion, these are combined as "grass", "sedge", or "feathermoss", the latter referring to finely branched mosses such as *Hylocomium splendens, Pleurozium scheberi* and *Rhytidium rugosum*. The genera are in approximate order of abundance, fidelity and indicator effectiveness, by strata. The two-way tables ordered and classified by TWISA are presented in Tables 3-6. The tables result from a classification of plots which is then used to classify the species according to their ecological preferences using the classification of plots as a basis. The plot and species classifications are then used together to obtain an ordered table which expresses the species synecological relations as succintly as possible. The species are ordered by their preference in terms of abundance to the dichotomy of plots.

The construction of the two-way table is done by identification of differential species which resembles the "hand" method of classification outlined by Mueller-Dombois and Ellenberg (1974, Chapter 9). In the method outlined by Mueller-Dombois and Ellenberg, the species are classified at the same time as the samples. This is different than the TWISA classification where the samples are classified first and the species are classified second, using the classification of the samples as a basis. The arrangement is approximately on the positive diagonal with an area in the middle of ubiquitous species and an area at the ends for anomalous species. The arrangement groups similar species

Table 2. Classification of core groups identified by TWISA. The alphanumeric codes for the core groups are used throughout the thesis.

Coniferous Forest

Picea mariana - Larix laricina

C1 *Larix laricina, Picea mariana, Andromeda polifolia, Eriophorum vaginatum, Sphagnum* spp.

C2 *Picea mariana - Larix laricina, Ledum palustre, Empetrum nigrum, Sphagnum* spp.

C3 *Picea mariana, Larix laricina, Ledum palustre, Eriophorum vaginatum, Sphagnum* spp.

C4 *Picea mariana-Larix laricina, Vaccinium uliginosum, Ledum palustre, Betula nana, Vaccinium vitis-idaea, Carex bigelowii, Sphagnum* spp.

C5 *Picea mariana, larix laricina, Vaccinium uliginosum, Ledum palustre, Rubus chamaemorus, Hylocomium splendens.*

Picea glauca

C6 *Picea glauca, Vaccinium vitis-idaea, Betula glandulosa, Empetrum nigrum,* feathermoss.

C7,C11 *Picea glauca, Betula nana, Salix planifolia, Carex* spp.

C8 *Picea glauca, Alnus crispa, Salix glauca, Equisetum arvense, Rubus arcticus,* feathermoss.

C9 *Picea glauca, Vaccinium uliginosum, Salix planifolia, Empetrum nigrum, Hylocomium splendens.*

C10 *Picea glauca, Alnus crispa, Vaccinium vitis-idaea, Hylocomium splendens, Stereocaulon* spp.

Table 2. Continued

C12 *Picea glauca, Salix glauca, Salix reticulata, Arctagrostis latifolia,* feathermoss, *Cladonia rangiferina, Cladonia amaurocrea.*

C13 *Picea glauca, Salix planifolia, Vaccinium uliginosum, Arctostaphylos rubra, Hedysarum alpinium, Hylocomium splendens.*

C14 *Picea glauca, Potentilla fruticosa, Salix planifolia, Festuca altaica, Bryales, Stereocaulon* spp.

C15 *Picea glauca, Oxytropis campestris, Agropyron violaceum, Dryas integrifolia, Bryales.*

Deciduous and Mixed Deciduous-Coniferous Forest

Populus balsamifera

M1 *Populus balsamifera, Salix alaxensis, Salix planifolia, Shepherdia canadensis, Arctostaphylos rubra, Senecio lugens, Hylocomium splendens.*

M2 *Populus balsamifera-Salix alaxensis, Salix glauca, Shepherdia canadensis, Senecio lugens.*

M3 *Populus balsamifera-Alnus crispa, Dryas drummondi, Shepherdia canadensis, Agropyron violaceum.*

Populus balsamifera - Picea glauca

M4 *Populus balsamifera-Picea glauca, Salix glauca, Juniperus communis, Elymus innovatus, Arctostaphylos uva-ursi, Hylocomium splendens.*

M5 *Populus balsamifera, Picea glauca, Salix alaxensis, Alnus crispa, Calamagrostis inexpansa, Tomenhypnum nitens.*

Table 2. Continued

M6 *Populus balsamifera, Picea glauca, Larix laricina, Alnus crispa, Salix alaxensis, Hedysarum alpinum, Epilobium angustifolium.*

M7 *Picea glauca, Populus balsamifera, Vaccinium uliginosum, Ledum palustre, Empetrum nigrum, Pyrola grandiflora, Hylocomium splendens.*

M8 *Populus balsamifera, Picea glauca, Salix alaxensis, Alnus crispa, Salix planifolia, Empetrum nigrum, Epilobium angustifolium, Hylocomium splendens.*

M9 *Populus balsamifera, Picea glauca, Alnus crispa, Rosa acicularis, Calamagrostis lapponica, Equisetum silvaticum, Polytrichium* spp.

Betula papyrifera - Picea glauca

M10 *Betula papyrifera, Alnus crispa, Rosa acicularis, Vaccinium vitis-idaea, Hylocomium splendens.*

M11 *Picea glauca, Betula papyrifera, Vaccinium uliginosum, Betula nana, Calamagrostis lapponica, Carex nesophila, Peltigera aphthosa.*

Betula papyrifera - Picea mariana - Larix laricina

M12 *Picea mariana, Betula papyrifera, Larix laricina, Ledum palustre, Vaccinium uliginosium, Vaccinium vitis-idaea, Empetrum nigrum,* feathermoss.

M13 *Larix laricina, Betula papyrifera, Picea mariana, Ledum palustre, Betula nana, Rubus chamaemorus, Eriophorum vaginatum, Oxycoccus microcarpus, Sphagnum* spp.

Table 2. Continued

Betula papyrifera

M14 *Betula papyrifera, Salix planifolia, Calamagrostis inexpansa, Carex aquatilis, Potentilla palustris.*

Low and Tall Shrub

Alnus crispa - Salix spp.

S1 *Alnus crispa-Salix alaxensis, Calamagrostis inexpansa, Rubus arcticus,* feathermoss.

S2 *Salix alaxensis, Salix glauca, Petasites hyperboreus, Calamagrostis inexpansa, Rosa acicularis.*

Alnus crispa - Salix spp. - *Betula nana*

S3 *Alnus crispa, Salix planifolia, Equisetum arvense, Arctagrostis latifolia, Carex bigelowii.*

S4 *Alnus crispa, Salix planifolia, Lycopodium annontinum, Calamagrostis inexpansa, Spirea beauverdiana,* feathermoss.

S5 *Betula nana, Salix barrattiana, Festuca rubra, Potentilla fruticosa, Hylocomium splendens.*

S6 *Alnus crispa, Betula nana, Salix planifolia, Empetrum nigrum, Vaccinium vitis-idaea, Hylocomium splendens.*

S7 *Salix glauca, Salix planifolia, Vaccinium uliginosum, Betula nana, Carex bigelowii, Hylocomium splendens.*

S8 *Salix planifolia, Salix reticulata, Carex podocarpa, Vaccinium uliginosum, Hylocomium splendens.*

S9 *Salix alaxensis, Salix planifolia, Petasites hyperboreus, Delphinifolium glaucum, Sanguisorba officinalis.*

Table 2. Continued

S10 *Salix barclayi, Equisetum palustre, Carex podocarpa, Hylocomium splendens.*

Salix spp. - *Shepherdia canadensis.*

S11 *Salix alaxensis, Salix barclayi, Epilobium angustifolium, Shepherdia canadensis.*

S12 *Salix alaxensis, Salix planifolia, Festuca altaica, Shepherdia canadensis, Hylocomium splendens.*

Salix spp.

S13 *Salix alaxensis, Betula nana, Festuca altaica, Salix reticulata, Dryas integrifolia.*

S14 *Salix barrattiana, Betula nana, Dryas integrifolia, Gentiana propinqua, Pleurozium scheberi.*

S15 *Salix alaxensis, Shepherdia canadensis, Dryas octopetala, Arctostaphylos rubra.*

S16 *Salix alaxensis, Salix arbusculoides, Alnus crispa, Artemesia tilesii.*

Dwarf Shrub and Shrub Tundra

Salix spp. - *Shepherdia canadensis*

T1 *Salix glauca, Shepherdia canadensis, Dryas integrifolia, Artemisia frigida, Festuca rubra.*

T2 *Salix glauca, Shepherdia canadensis, Vaccinium uliginosium, Dryas integrifolia, Saxifraga tricuspidata, Polytrichium commune.*

Table 2. Continued

Salix spp.

T3 *Salix glauca, Salix reticulata, Festuca altaica, Dryas octo-petala.*

T4 *Salix brachycarpa, Salix reticulata, Dryas octopetala, Cassiope tetragona,* feathermoss.

Dryas octopetala

T5 *Dryas octopetala, Salix arctica, Carex microchaeta, Vaccinium uliginosium, Hylocomium splendens.*

T6 *Dryas octopetala, Salix arctica, Oxytropis nigrescens, Carex microchaeta, Hylocomium splendens.*

T7 *Salix arctica, Salix reticulata, Dryas octopetala, Poa arctica, Luzula tundricola, Carex microchaeta, Hylocomium splendens.*

T8 *Cassiope tetragona, Dryas octopetala, Salix reticulata, Salix arctica, Hylocomium splendens, Stereocaulon* spp.

Carex - Sphagnum

T9 *Carex canescens, Carex rhynchophysa, Agropyron violaceum, Rorippa islandica, Sphagnum* spp.

Betula nana - Ericaceous - Salix spp.

T10 *Betula nana, Vaccinium uliginisium, Ledum decumbens, Dryas octopetala, Salix arctica, Salix reticulata,* feathermoss.

Betula nana - Salix spp.

T11 *Salix planifolia, Betula nana, Spirea beauverdiana, Calamagrostis lapponica, Petasites hyperboreus,* feathermoss.

T12 *Salix planifolia, Betula nana, Salix glauca, Vaccinium uliginosum, Arctagrostis latifolia,* feathermoss.

Table 2. Continued

Salix spp.

T13 *Salix reticulata*, *Eriophorum angustifolium*, *Dryas integrifolia*, *Carex membranacea*, *Sphagnum* spp.

T14 *Carex microglochin*, *Hedysarum alpinium*, *Potentilla fruticosa*, *Juncus castaneus*, *Sphagnum* spp.

Table 3. Two-way table ordered and classified by TWISA of the coniferous forest data. Abbreviations of species names are shown at the left with the abbreviations defined in Appendix IV. Consecutive numbers coding the plots are along the top divided into their core group type with the code explained in Appendix III. The values within the table indicate categories of abundance with absence of a species represented by the symbol "-". Vertical lines separate classes of plots at level 4. The horizontal lines separate classes of species at level 4.

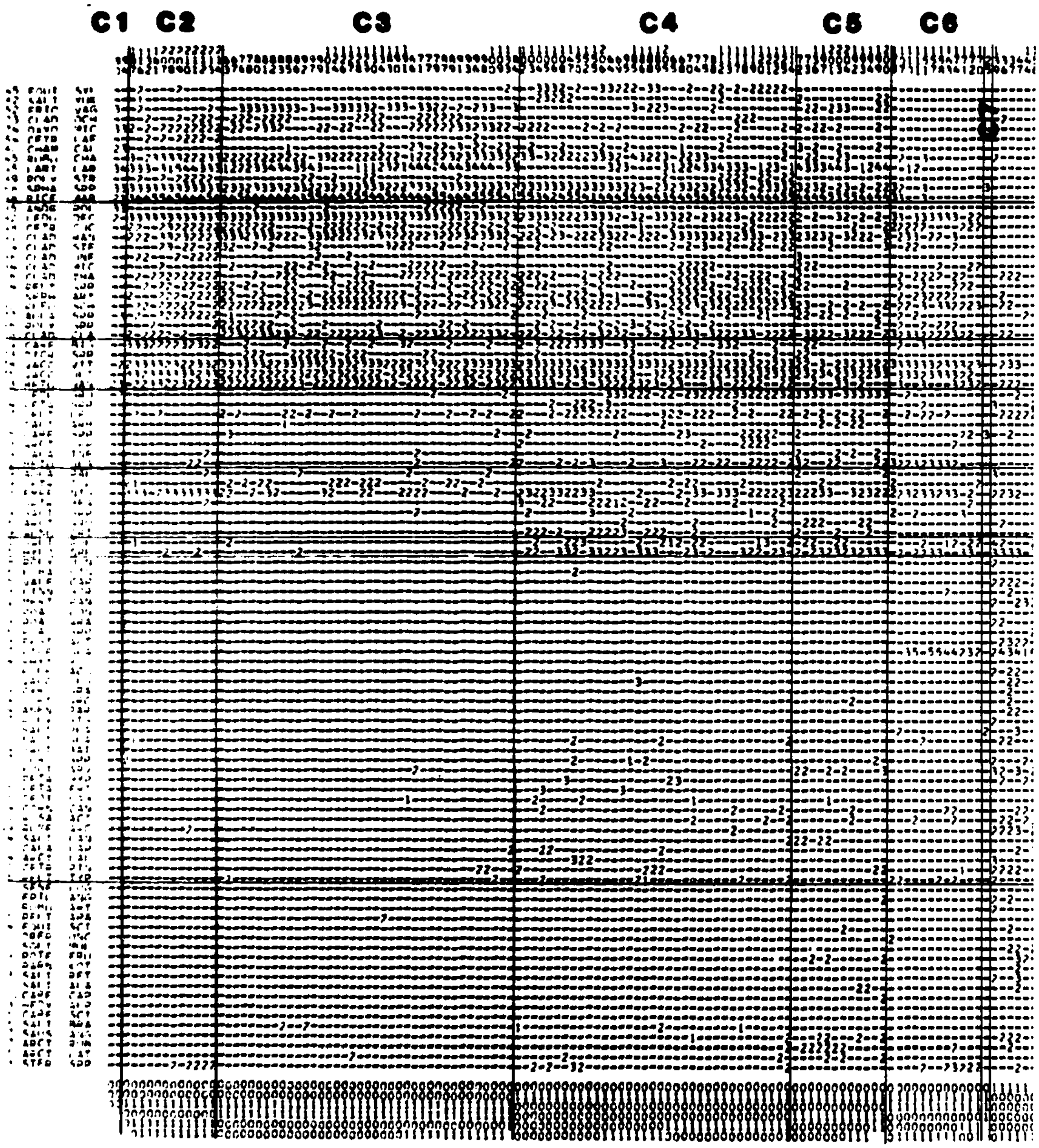

C1
C2
C3
C4
C5
C6

Table 3. Continued.

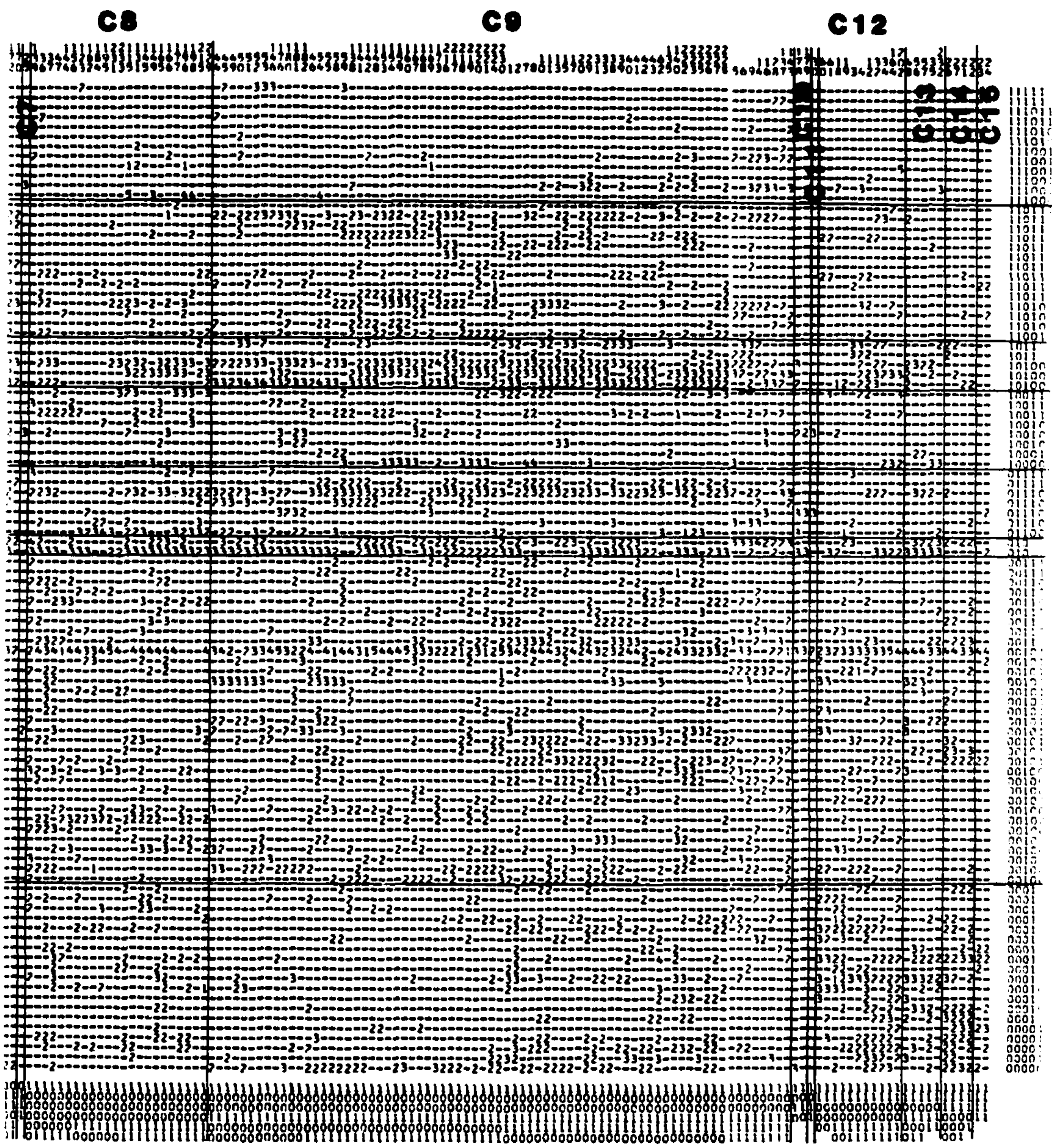
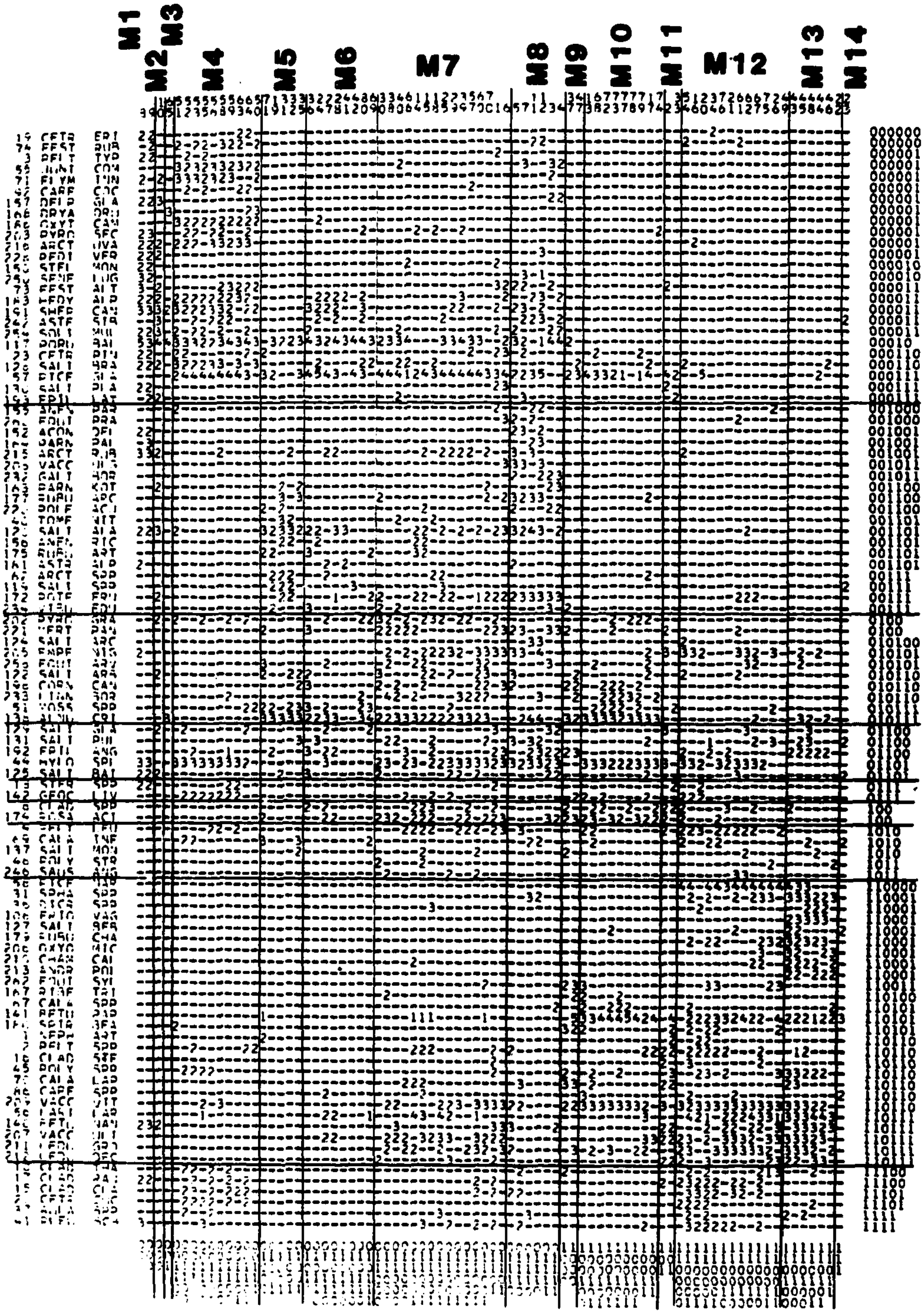


Table 4. Two-way table ordered and classified by TWISA of the deciduous and mixed deciduous-coniferous forest data. Abbreviations of species names are shown at the left with the abbreviations defined in Appendix IV. Consecutive numbers coding the plots are along the top divided into their core group type with the code explained in Appendix III.

The values within the table indicate categories of abundance with absence of a species represented by the symbol "-". Vertical lines separate classes of plots at level 4. The horizontal lines separate classes of species at level 4.



M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
M13
M14

Table 5. Two-way table ordered and classified by TWISA of the low and tall shrub data. Abbreviations of species names are shown at the left with the abbreviations defined in Appendix IV. Consecutive numbers coding the plots are along the top divided into their core group type with the code explained in Appendix III. The values within the table indicate categories of abundance with absence of a species represented by the symbol "-". Vertical lines separate classes of plots at level 4. The horizontal lines separate classes of species at level 4.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6. Two-way table ordered and classified by TWISA of the dwarf shrub and shrub tundra data. Abbreviations of species names are shown at the left with the abbreviations defined in Appendix IV. Consecutive numbers coding the plots are along the top divided into their core group type with the code explained in Appendix III. The values within the table indicate categories of abundance with absence of a species represented by the symbol "-". Vertical lines separate classes of plots at level 4. The horizontal lines separate classes of species at level 4.

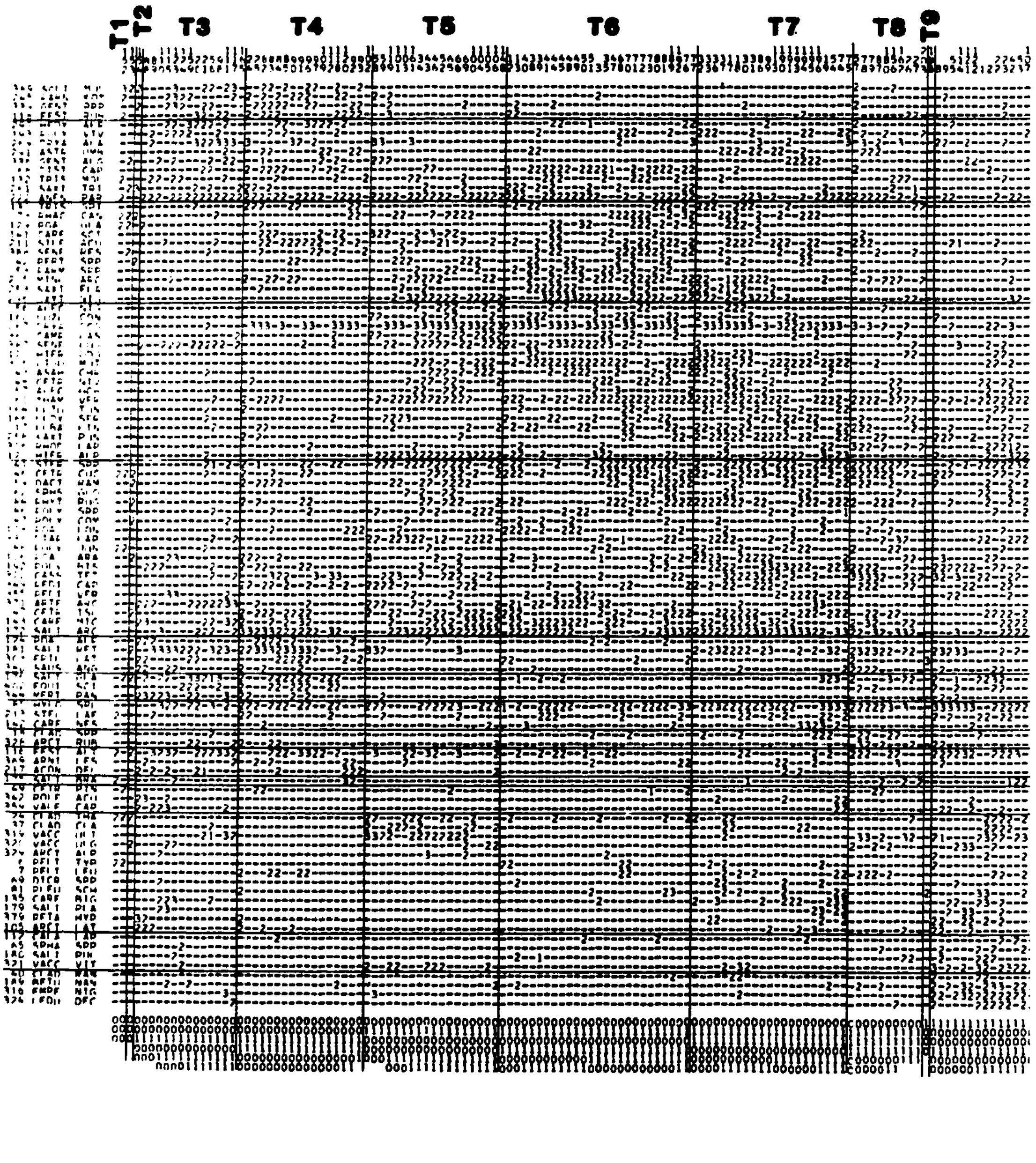

T1
T2
T3
T4
T5
T6
T7
T8
T9

Table 6. Continued.

T6	T7	T8	T9	T10	T11	T12	T13	T14	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

together and similar plots together. The diagnostic species for the core groups of plots are therefore, approximately in the boxes on the positive diagonal.

All species were used in the classification analysis but to reduce the size to a manageable level, only the 100 most common species are listed in these tables. Therefore, some of the rare indicator species may not be included in Tables 3-6. These indicators are listed in the dendrograms (Figs. 2-5).

The sequence of plots and species reflects a moisture gradient. The groupings show continuities in that many species decline gradually in abundance and are replaced gradually by others. Other species and plots show sharp discontinuities.

The DCA results confirm the classification presented. The cluster core groups appear reasonable and rather homogenous in the two dimensional diagram of sample plot ordination scores derived from the primary and secondary DCA axes (Figs. 6 and 7). Gradations between major groups occur. This mosaic effect between groupings is possibly due to two reasons. First the results of a data reduction technique reflect both the data and the technique. The nature of the ordination technique used recognizes the multivariate nonlinear continuous character of vegetation. Second, the inherent lack of structure in the data may reflect the following: (a) the species of the study area have a wide ecological amplitude [i.e., understory species of *Picea* stands extend onto tundra as well]; (b) the stratified random sampling technique resulted in the sampling of ecotones, and the variation is therefore primarily continuous;

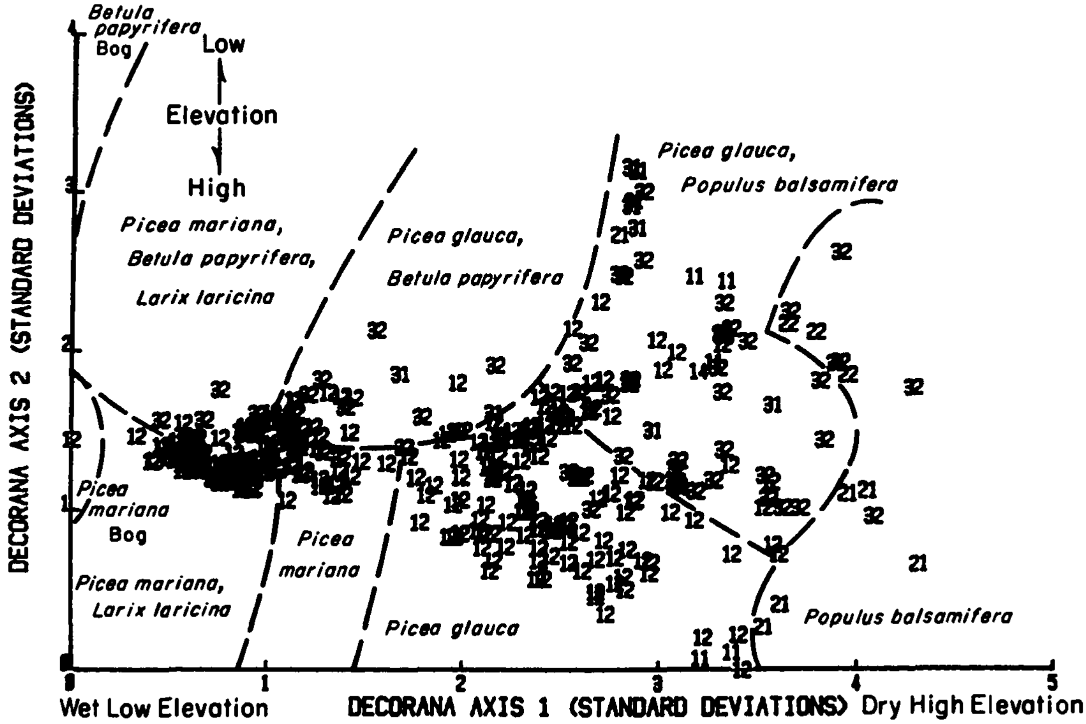


Figure 6. Community positions along the first two axes of variation of the DCA run on the forested plots (315 plots, 409 species). The broken lines indicate approximate boundaries between the major overstory types. The plot positions are indicated by numbers symbolizing the codes for level II and level III of the PAVC which are delineated in Appendix II. The PAVC is the subjective classification developed for the study area by me within the basic structure of the provisional classification framework for Alaskan vegetation (Viereck and Dyrness, 1976).

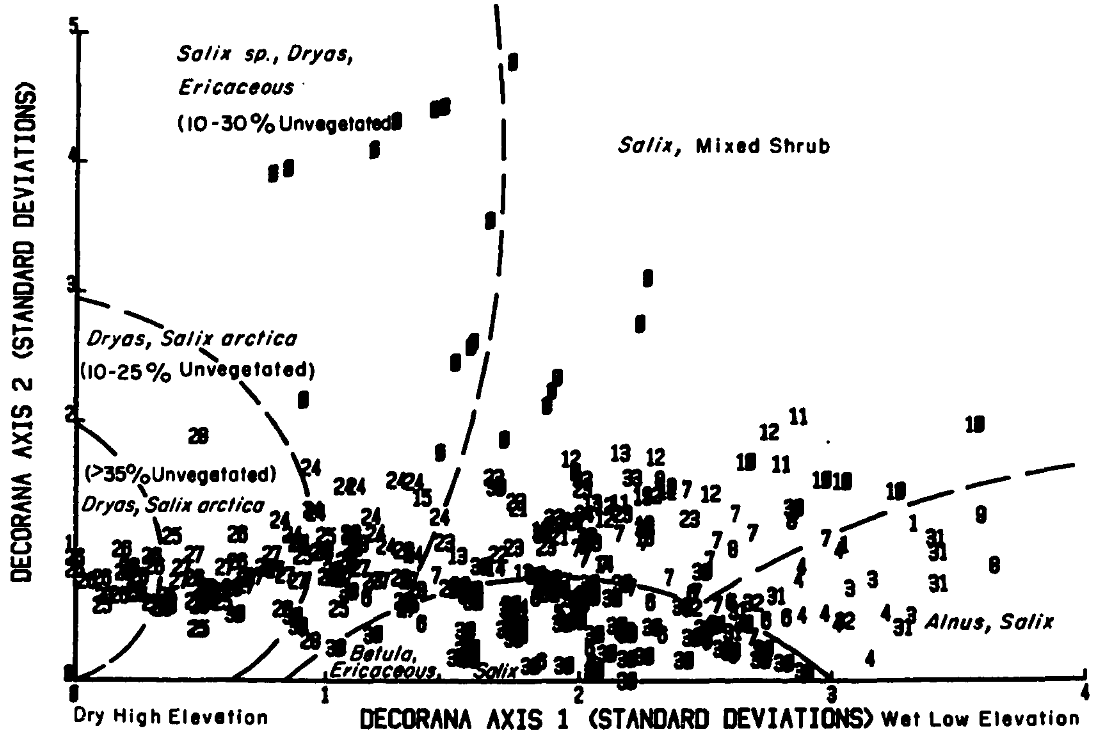


Figure 7. Community positions along the first two axes of variation of the DCA run on the unforested plots (312 plots; 489 species). The broken lines (--) indicate approximate location of the boundaries between the major overstory types. The plot positions on the ordination axis are represented by the codes for their core groups as follows: Numbers 1 to 16 represent S1 to S16; Numbers 21 to 35 represent T1 to T14 respectively; the Ø represents outlying plots which were omitted from the analysis.

(c) the data collection procedures were designed to sample a large land area to meet the objectives of the study, and therefore the data set is very heterogeneous with high dimensionality. Stage two and three phases of analysis led to rearrangements of plots, but the relationships between the core groups of plots and the gradients reflected are generally constant.

The degree of change in species composition of communities along a gradient is beta diversity (Whittaker, 1970). The derived unit of distance along the DCA ordination gradient may be termed a "standard deviation", as the root-mean square standard deviation of the species abundance profiles is approximately one in a typical sample.

Four standard deviations correspond approximately to the distance over which a species appears, rises to its mode, and disappears again (Hill, 1979). For each axis the length of the gradient is the length of the sample ordination. A sample ordination of length four standard deviations means that the majority of the species occurring at one end of the gradient is completely absent at the other end. The variance on the DCA ordination axis is represented by the eigenvalue derived from the data. In general, axes with the largest eigenvalues account for the greatest proportion of the variability and the structure of sample points is concentrated within this direction. Axes for which the eigenvalue is much less than the largest eigenvalue are of less significance in terms of information content. If the variances are nearly equal, the structure of sample points is concentrated within three or four dimensions.

Table 7 illustrates the relationship between the four ordination axes for the data matrices at all stages of the analysis.

When the entire data set was analyzed, all four axes were close in value which illustrates the many factors influencing the dimensionality of the data set. At stage 2 the unforested plots ordination resulted in axes 1 and 2 eigenvalues more similar than the eigenvalues for forested plots ordination. At stage 3, the shrub data illustrated the greatest variability as the second axis was closer in value to the first axis than in the other data sets. This is possibly due to the variability attributable to the successional state of the shrub data.

Figures 2 through 5, and Table 2 illustrate high variation in all four major axes which suggests complexity of pattern in the data and a high dimensionality of underlying environmental relationships. Numerous complex and interacting environmental factors will produce data in which the variance will not be concentrated in any single axis of variation.

As a result of the random selection of sample points the core plot community descriptions are more variable than typical vegetation studies, e.g., Foote (1976). For this reason it is difficult to precisely define the underlying environmental relationships.

Reciprocal Averaging and therefore DCA, is most useful in revealing the primary direction of sample variation in response to environmental variation (Gauch *et al.*, 1979). Correlation or regressions may be computed between environmental factors and DCA ordination scores (Austin, 1971). These correlations may give ambiguous results because of oblique or non-linear relationships so typical of vegetation studies. Graphing

Table 7. The variance and length of sample ordination gradient resulting from detrended correspondence analysis.

Stage 1	Axis Number	Variance	Length of Gradient in Standard Deviation Units
Entire Data Set	1	.59327	5.870
627 plots	2	.45725	5.109
	3	.35330	7.822
	4	.33709	4.980
Stage 2			
Unforested plots	1	.4085	3.649
303 plots	2	.34407	4.747
Rare Species Down	3	.18989	4.383
weighted	4	.14528	2.960
Forested plots	1	.52791	4.322
310 plots	2	.21898	3.147
Rare Species Down	3	.16256	2.791
weighted	4	.12267	3.067
Stage 3			
Conifer	1	.55157	4.350
233 plots	2	.39079	3.642
	3	.27333	3.905
	4	.21634	3.235

Table 7. Continued

Stage 1	Axis Number	Variance	Length of Gradient in Standard Deviation Units
Mixed Conifer and	1	.58369	4.710
Deciduous	2	.38354	3.868
78 plots	3	.25432	3.374
	4	.22897	2.852
Tundra	1	.46951	4.460
183 plots	2	.33262	4.106
	3	.26410	3.632
	4	.21553	2.997
Shrub	1	.45069	4.592
96 plots	2	.39053	3.381
	3	.30401	3.629
	4	.24079	3.118

environmental variables can reveal such relationships in the form of curvilinear trend surfaces.

The interpretation of ordination results in relationship to environmental gradients, is confounded by at least four considerations.

1. Environment and species interact as changes in species abundances are related to changes in environmental factors and competition from other species.
2. Variation in vegetation may be found over an area in which there are no significant differences in present environment. This variation may be attributable to history of the area and species and quantity of propogating bodies available from neighboring areas.
3. Interchanges among ecological equivalents in a given area can result in variation and reduce replicate similarity. There may be several species which grow readily and interchanges among them do not imply ecological or environmental differences (Dale, 1977).
4. Fluctuations in species abundances may be due to random effects. These effects include the unpredictable variance due to seed and pollen dispersal, germination, animal activities and the variance remaining in raw data after subtracting that accounted for by known causes, including history.

Definition of Relationships Between Core Groups

The sequence of core groups resulting from TWISA at all stages of analyses reflects a moisture gradient.

The positions of the community types along the first two axes of variation of the DCA ordination analysis of data matrices divided on the basis of the presence of a tree strata are illustrated in Figures 6 and 7.

The positions of the core groups in the X-Y DCA ordination plane at stage 2 level of analysis are illustrated in Figures 8 and 9. The basic horizontal trend for the forested core groups is related to a moisture gradient (Fig. 8). The moisture gradient is also apparently confounded with environmental factors as elevation, soil temperature, aspect, slope, and soil drainage. The first axis clearly separates the forested stands situated in the dry areas from those in the wet areas. The dashed line indicates an approximate location of the physiographic boundary between forested plots of the Tanana-Kuskokwim lowland area and those of the eastern northern foothills area (Fig. 8). Both the first and second axes illustrate a sequence of forested plots related to an elevation gradient. Axis 3 of the forested plot ordination illustrates a gradient related to age of plots and successional characteristics of the stand (Fig. 10). The plots in group 13 were all young mixed deciduous and conifer plots which were burned in 1968 to 1972.

The basic horizontal trend for the untreed plots is also a moisture gradient and involves environmental factors as elevation, aspect, slope and soil drainage. The dotted line is an elevational boundary and separates mat and cushion tundra plots from shrub tundra and shrubland plots (Fig. 9). The first and second axes of variation for the unforested plots are related to elevation.

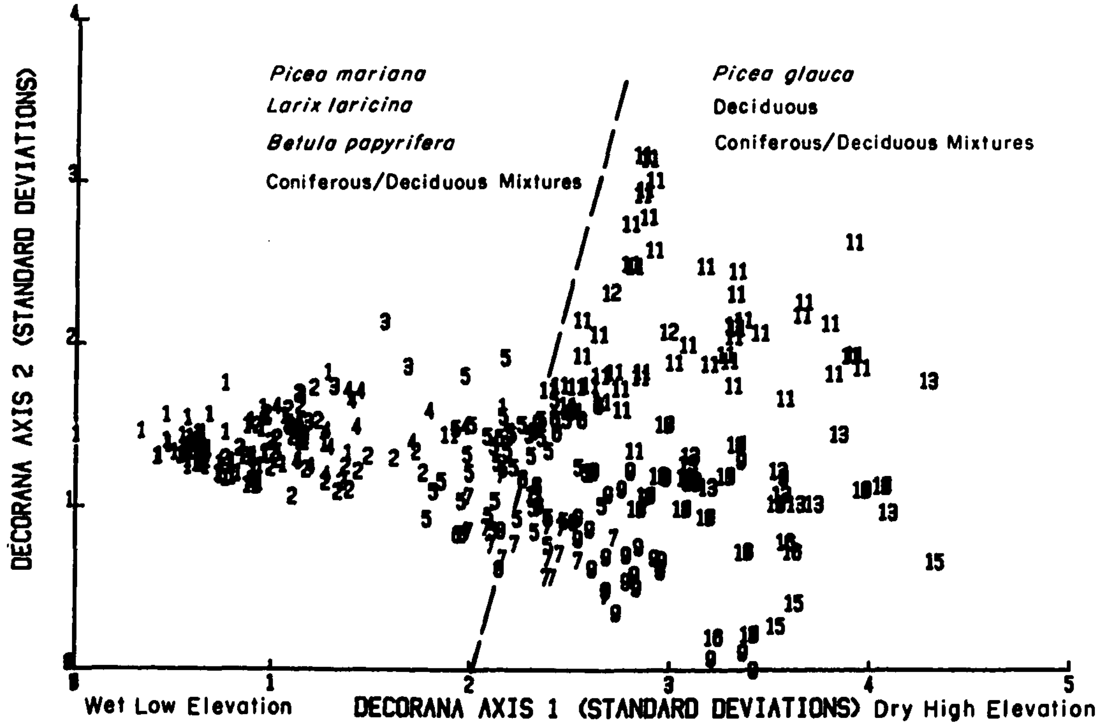


Figure 8. Plot positions along the first two axes of variation of the DCA of the forested plots. The broken line (--) indicates an approximate boundary between the plots of the Tanana lowland region and the plots of the northern foothills region. The numbers marking the location of the plots in the X-Y ordination plane symbolize the codes for core groups TT1 to TT15. The broken line also indicates an approximate boundary between the types with *Picea mariana* and *Larix laricina* represented and the types with *Picea glauca* represented.

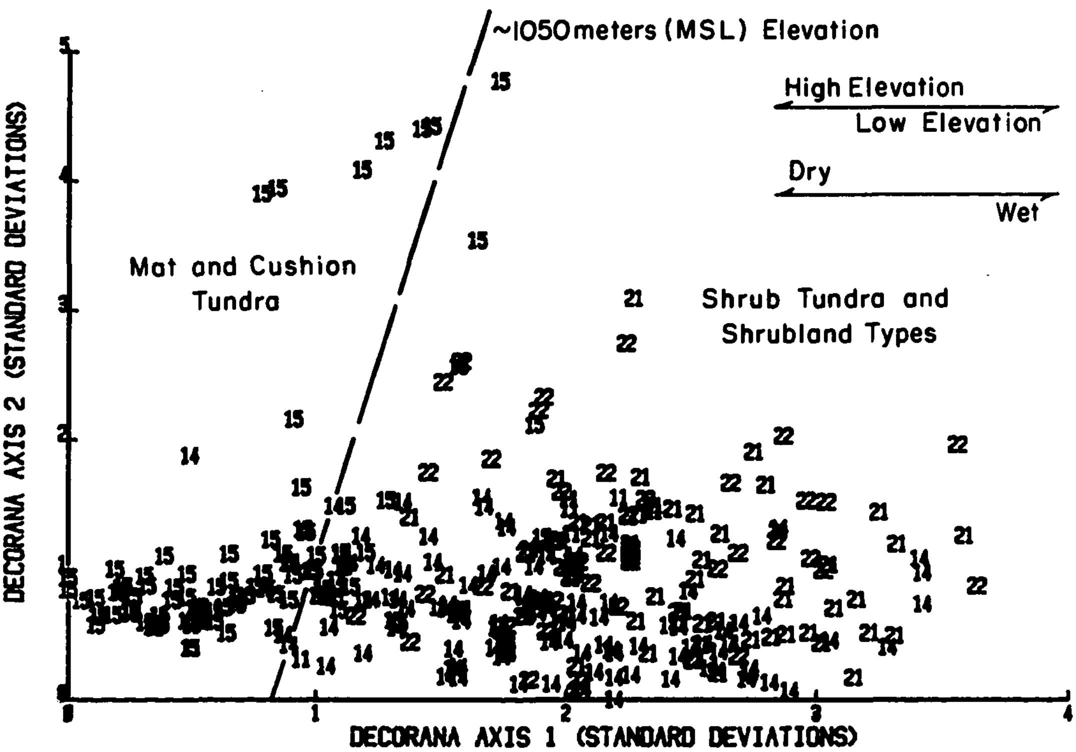


Figure 9. Plot positions along the first two axes of variation of the DCA of the unforested plots. The broken line (--) indicates an approximate boundary of plots present above 1,050 m and plots below 1,050 m.

The plot positions are indicated by two digit numbers symbolizing the codes for level I and level II of the PAVC which are delineated in Appendix II. The 1,050 m elevation boundary also presents a boundary between the mat and cushion tundra types and the shrub tundra-shrubland types.

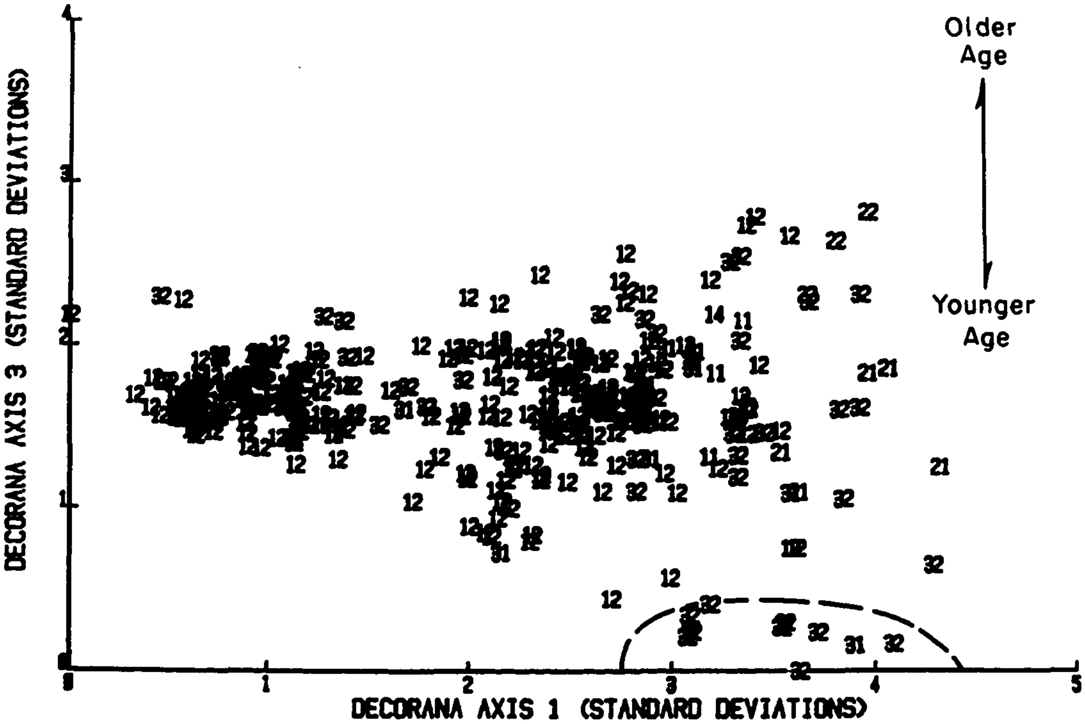


Figure 10. Plot positions along the first and third axes of variation of the DCA of the forested plots. The broken line (--) indicates the separation of a group of plots that were in the early stages of succession after a fire. The third axis is related to variation associated with age or a disturbance factor. The plot positions are indicated on the figure by two digit numbers symbolizing the codes for levels II and III of the PAVC which are delineated in Appendix II.

Description of Relationships Between Gradients

The value of an environmental measurement is shown for each sample plot instead of graphing core group numbers on the sample ordination plane. The environmental measurement values are more informative than correlations or regressions which could be computed between environmental factors and ordination scores. Graphing environmental variables reveals oblique or non-linear relationships which are less clearly revealed by correlations or regressions. The relationship of elevation and percent slope of the forested plots to DCA axis 1 is shown in Figures 11 and 12. Figures 13 and 14 illustrate the relationship of elevation and percent slope of the unforested plots to DCA Axis 1.

The positions of the core groups in the X-Y DCA ordination plane at stage 3 level of analysis are illustrated in Figures 15, 16, 17, and 18. Axis 1 for the coniferous plots (Fig. 15) clearly separates the wetter vegetation types from the dryer types. The second axis shows less variation in standard deviation values in the wetter groups (C1-C5, *Picea mariana, Larix larcina* core groups) than in the *Picea glauca* core groups (C6-C15).

When environmental values for the coniferous plot data are plotted against standard deviation values for axis 1, the ordination distance can be interpreted as a trend from low elevation, flat areas to high elevation south-facing valley slopes (Figs. 19, 20, 21). The moisture trend is from standing pools or poorly drained areas to dryer areas as standard deviation values for axis 1 increase. The sequence in surficial geology as ordination distance increases along axis 1 is eolian, lacustrine,

Figure 11. The elevation in meters (msl) of the forested plots is plotted against standard deviation values of the plots for the first axis of variation of the DCA ordination.

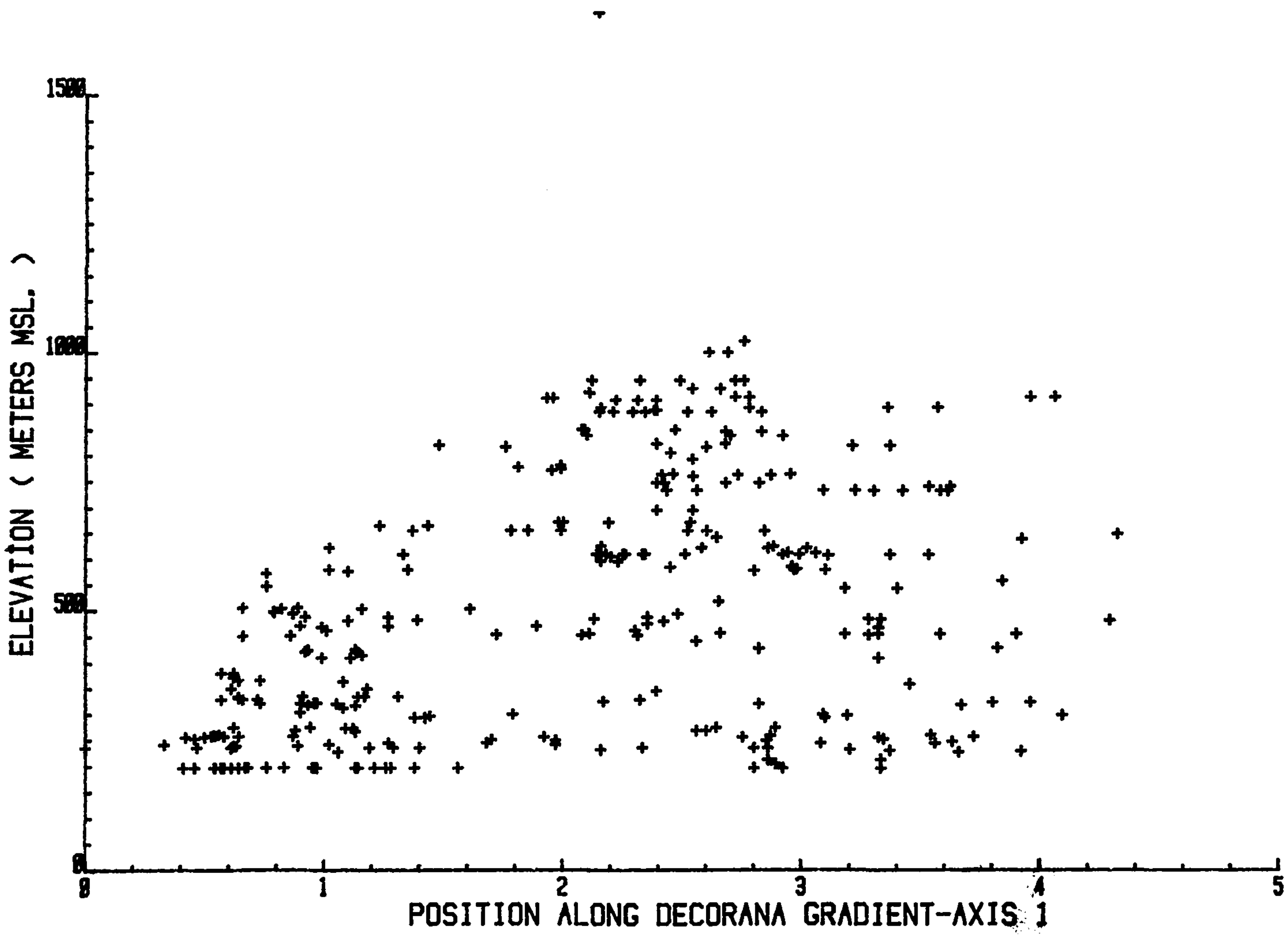

1500
1000
500
0
ELEVATION (METERS MSL.)
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 12. The percent slope of the forested plots is plotted against standard deviation values of the plots for the first axis of variation of the DCA ordination.

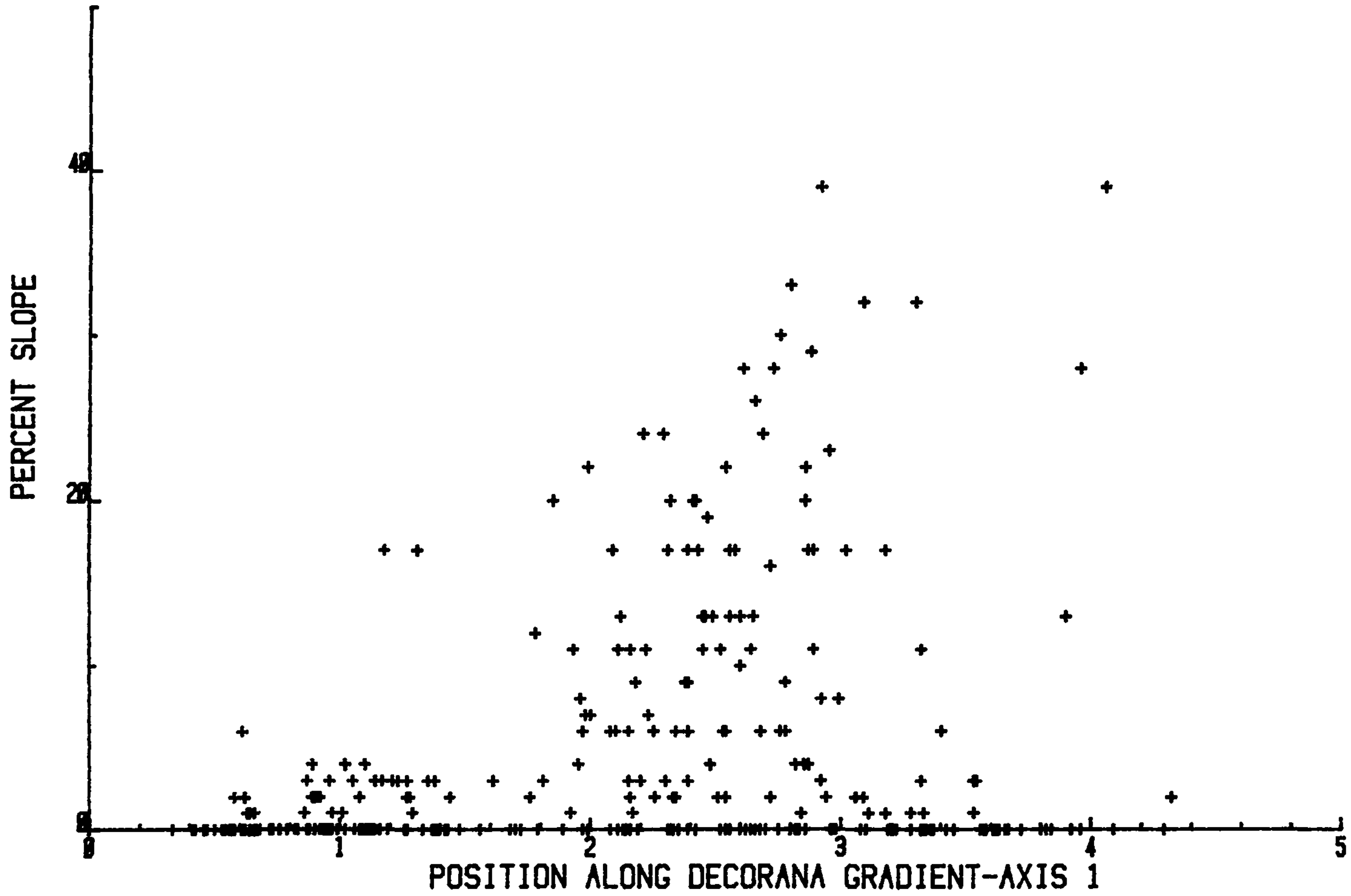
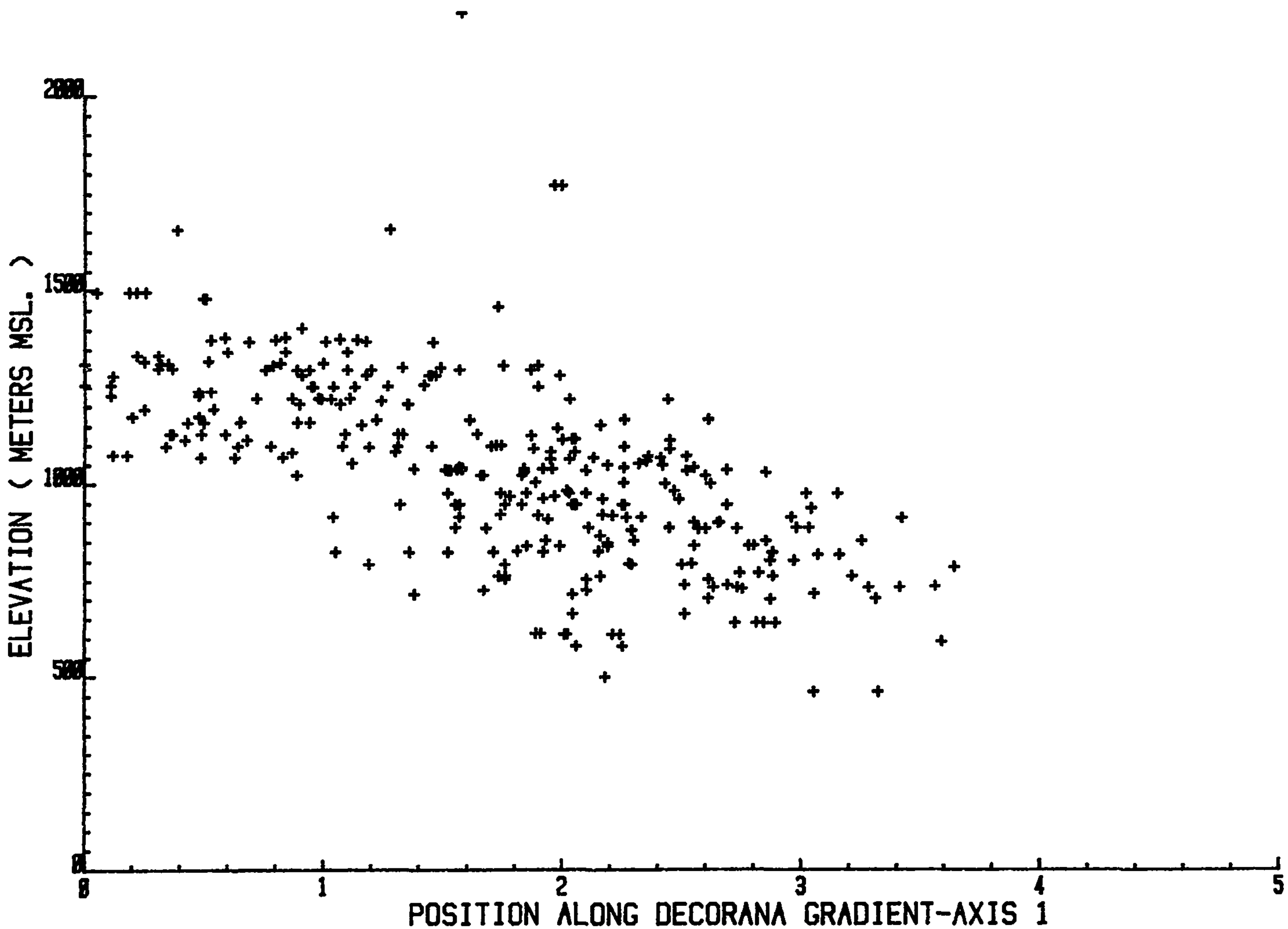

PERCENT SLOPE
40
20
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 13. The elevation in meters (msl) of the unforested plots is plotted against standard deviation values of the plots for the first axis of variation of the DCA ordination.



ELEVATION (METERS MSL.)
2000
1500
1000
500
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 14. The percent slope of the unforested plots is plotted against standard deviation values of the plots for the first axis of variation of the DCA ordination.

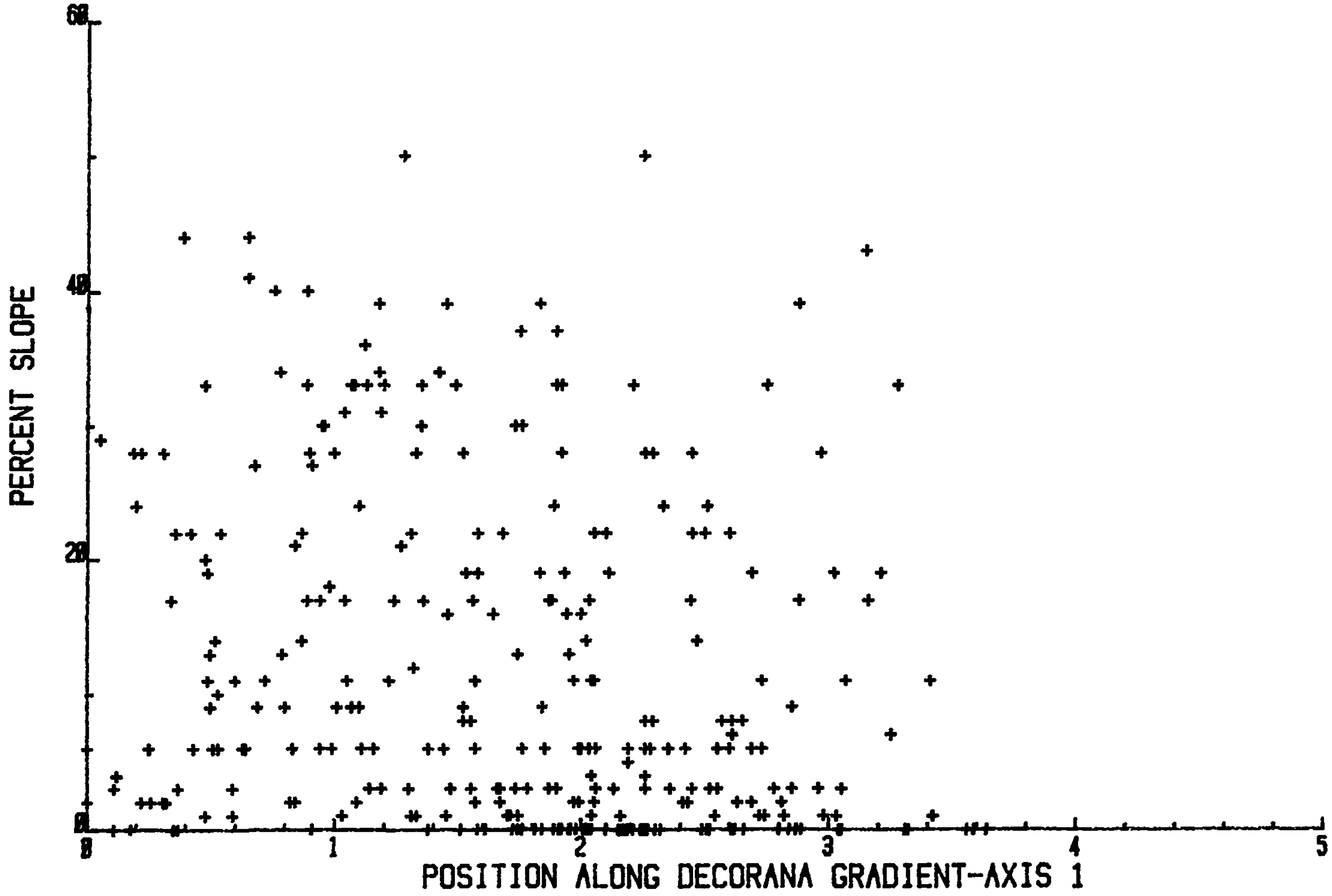

PERCENT SLOPE
60
40
20
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 15. Plot positions along the first two axes of variation of the DCA of the coniferous forest data (233 plots; 348 species). The plot positions are indicated on the figure by the core group numbers 1-15 which symbolize C1 to C15 respectively. This code is used throughout the thesis and explained in the text.

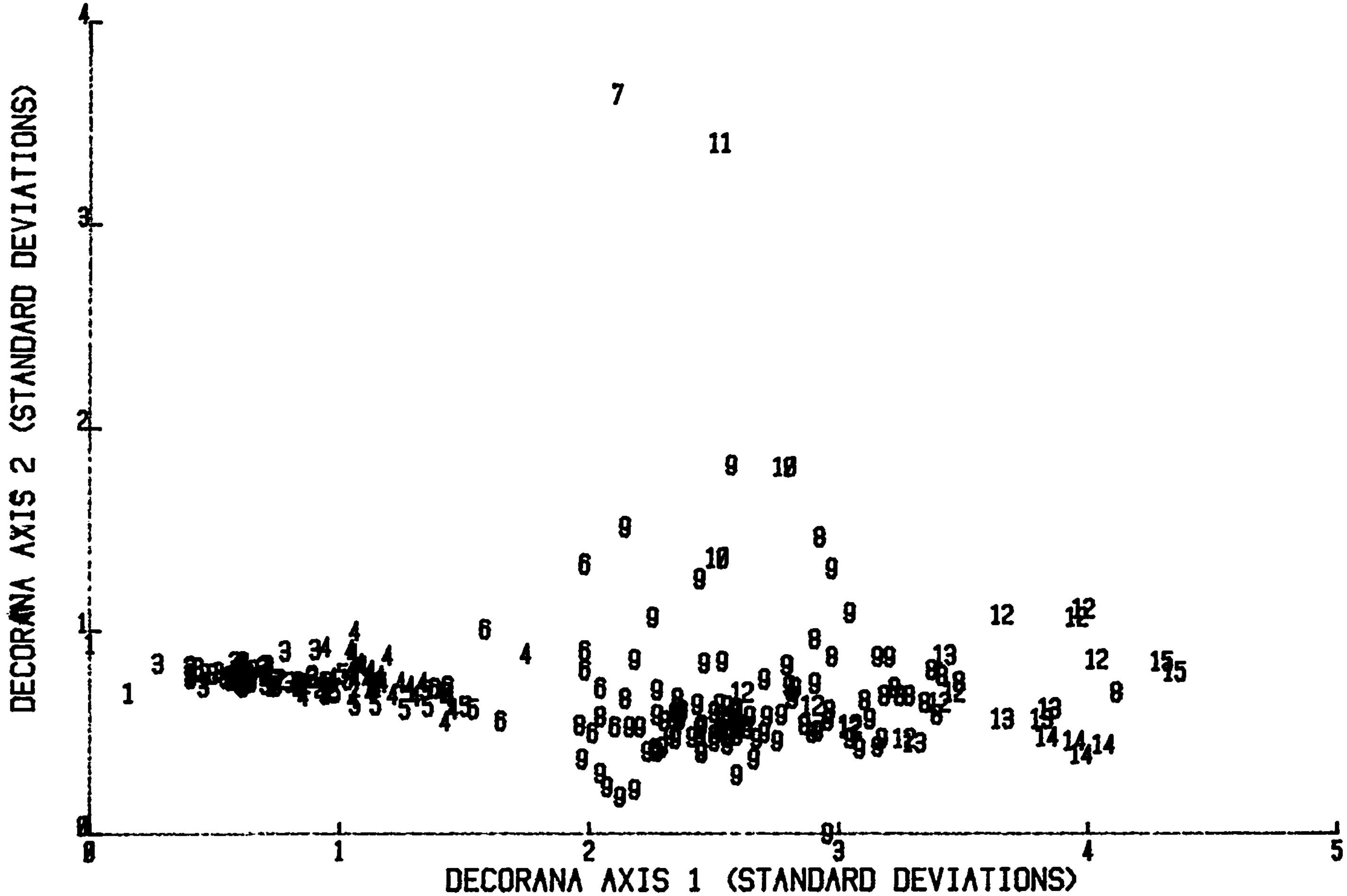

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 16. Plot positions along the first two axes of variation of the DCA of the deciduous and mixed deciduous-coniferous forest data (80 plots; 263 species). The plot positions are indicated on the figure by the core group numbers 1-14 which symbolize M1 to M14 respectively. This code is used throughout the thesis and explained in the text.

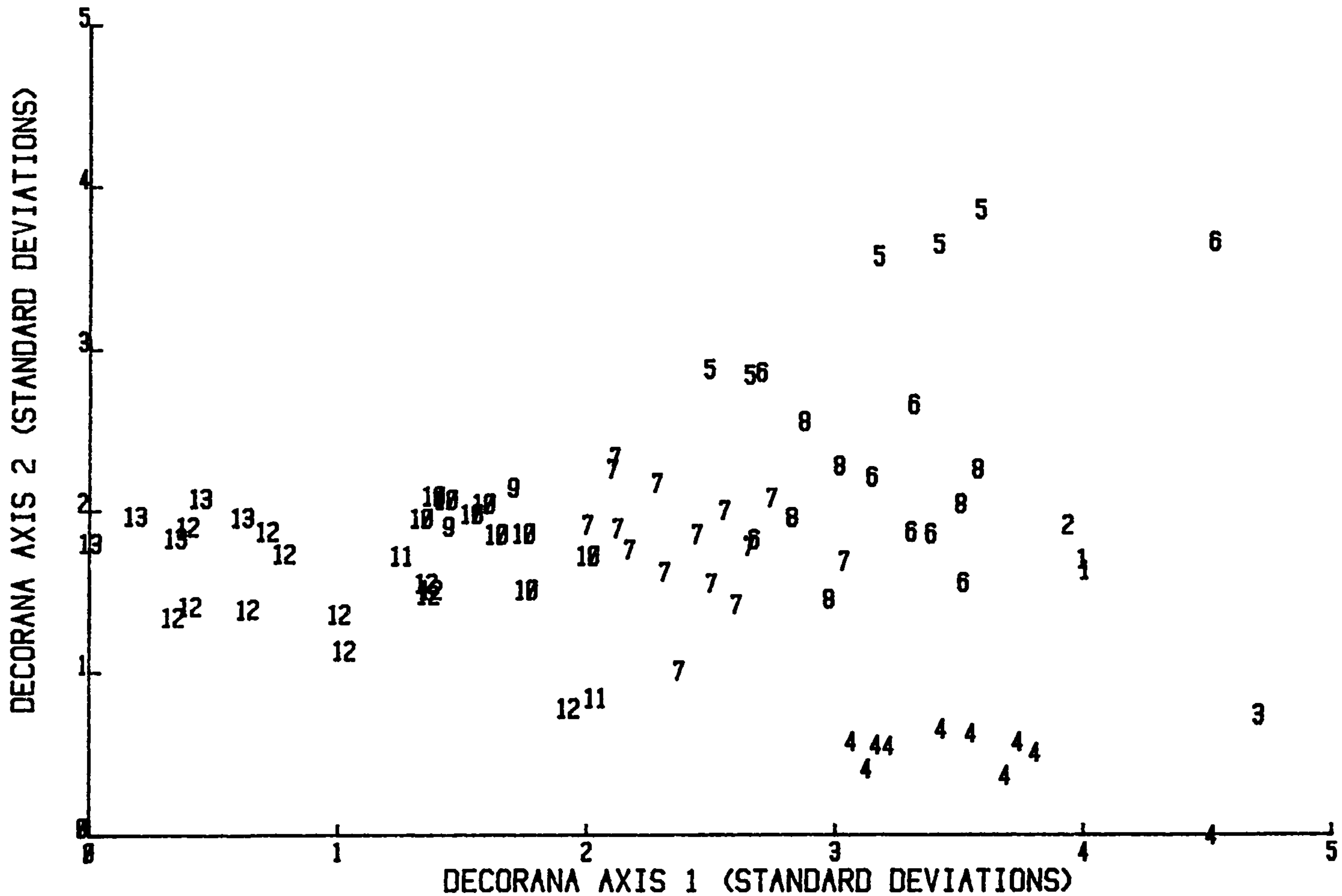

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 17. Plot positions along the first two axes of variation of the DCA ordination of the low and tall shrub data (96 plots; 344 species). The plot positions are indicated on the figure by the core group numbers 1 to 16 which symbolize S1 to S16 respectively. This code is used throughout the thesis and explained in the text.

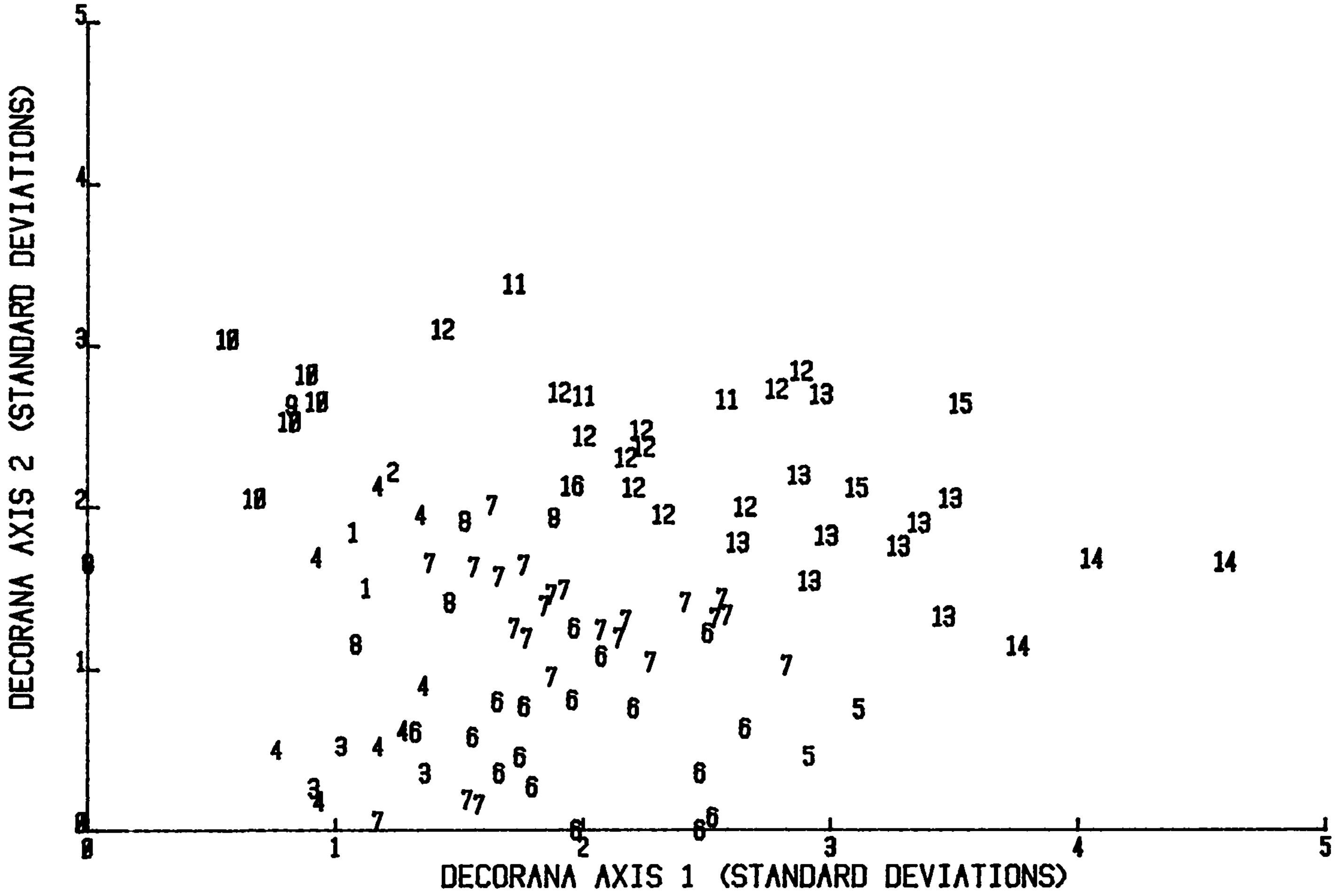

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

Figure 18. Plot positions along the first two axes of variation of the DCA ordination of the dwarf shrub and shrub tundra data (183 plots; 404 species). The plot positions are indicated on the figure by the core group numbers 1 to 14 which symbolize T1 to T14 respectively. This code is used throughout the thesis and explained in the text.

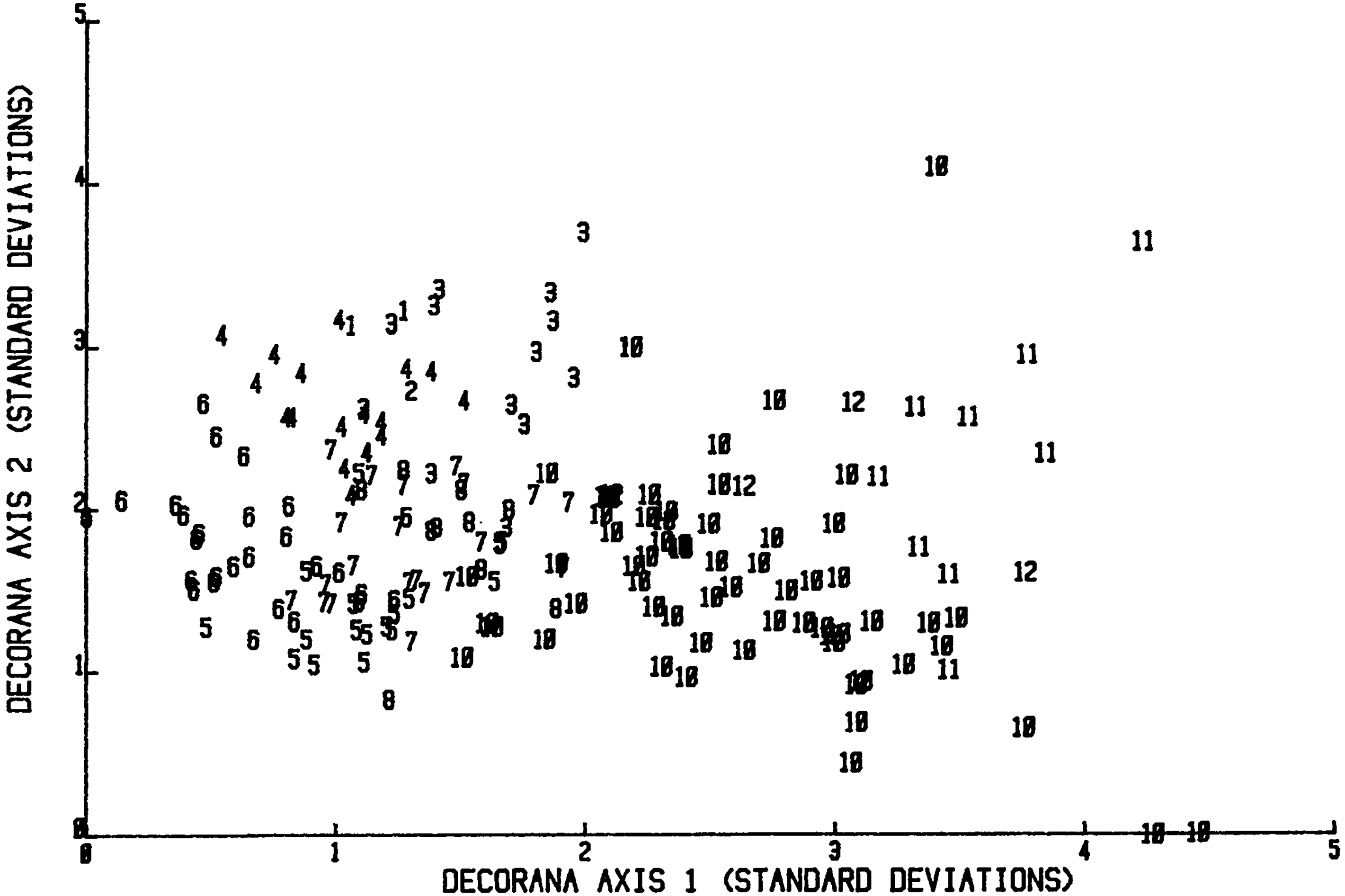

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 19. The elevation of the coniferous plots along the first axis of variation of the DCA ordination.

Elevation in meters (msl) is plotted against standard deviation values for the plots.

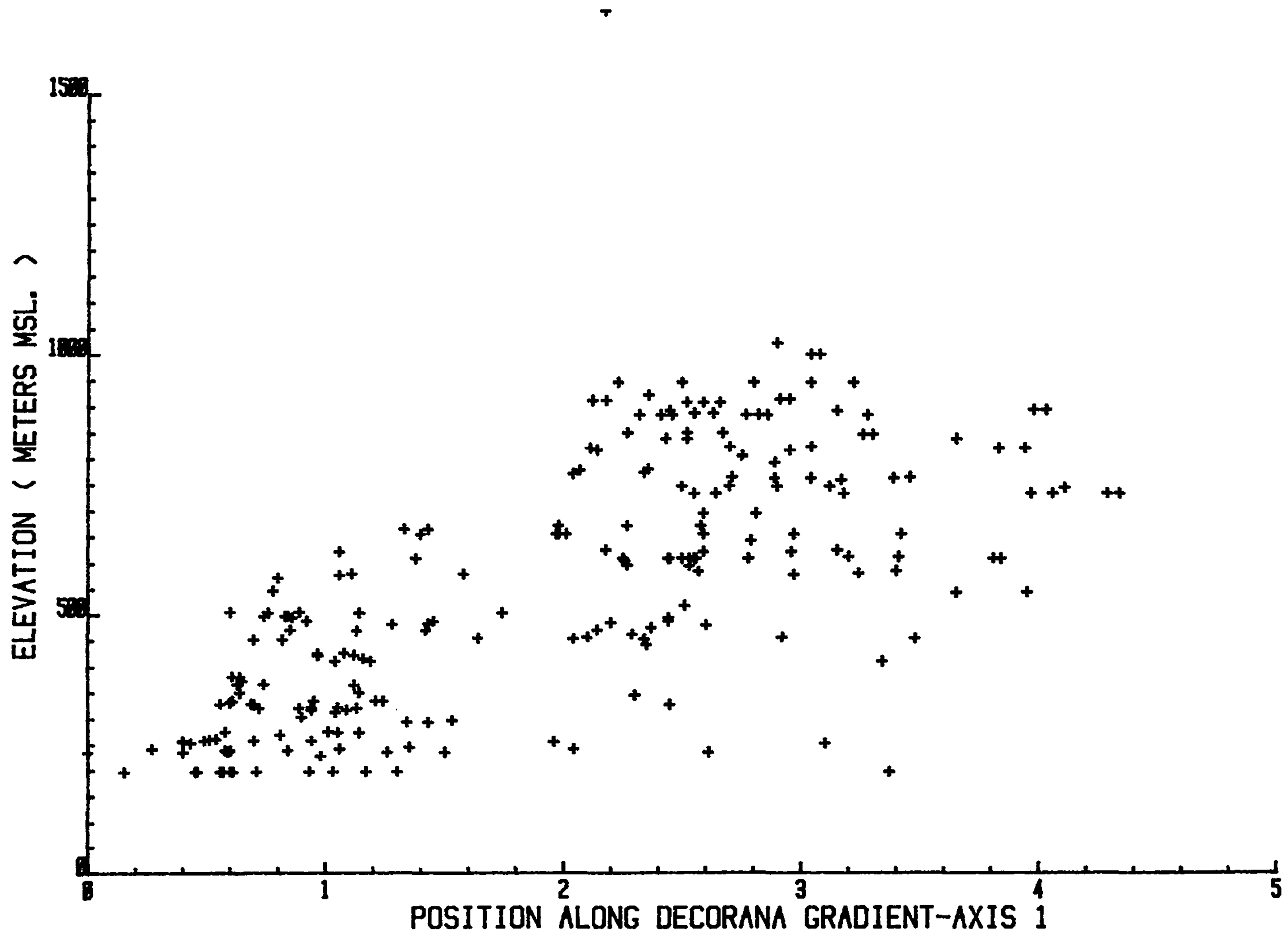

1500
1000
500
0
ELEVATION (METERS MSL.)
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 20. The percent slope of the coniferous plots along the first axis of variation of the DCA ordination.

The slope percent is plotted against standard deviation values for the plots.

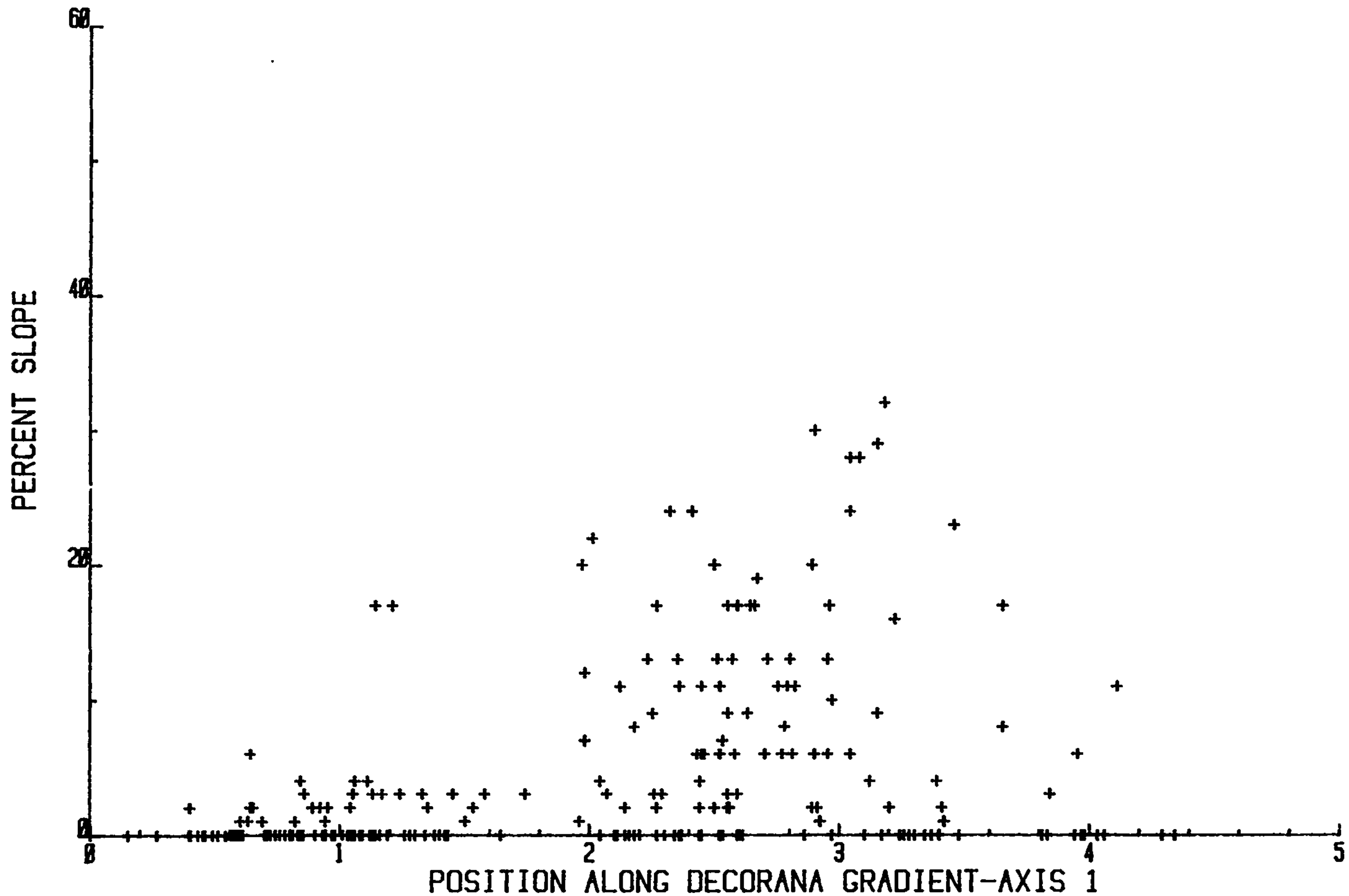

PERCENT SLOPE
60
40
20
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 21. The position on the slope of the coniferous plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes as follows:

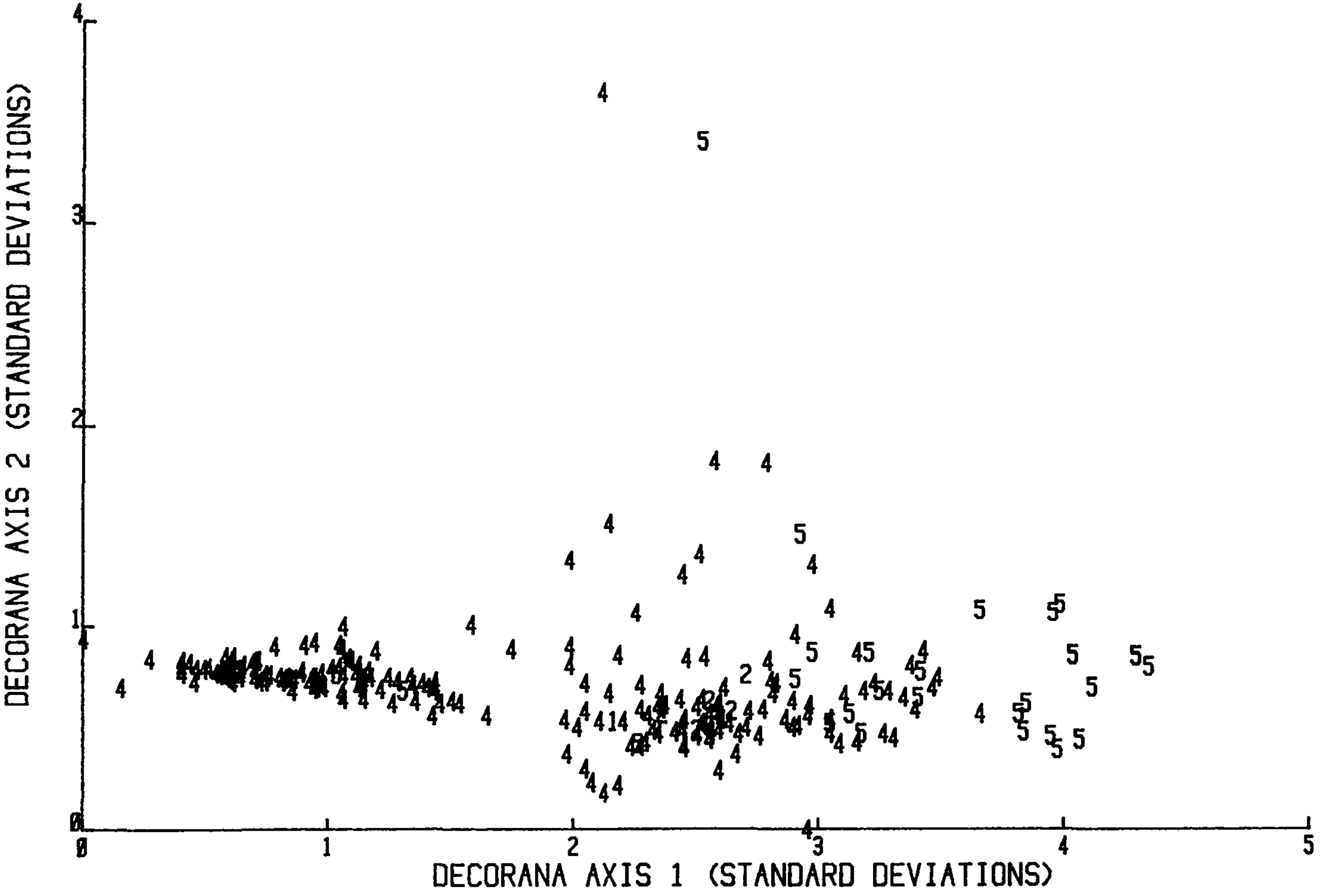
1 = ridgetop

2 = upper half

3 = midslope

4 = lower half

5 = valley


DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

glacial/fluvial undifferentiated, older moraines, alluvial/colluvial undifferentiated bedrock to alluvial (Fig. 22). The bedrock geology was largely unknown for the coniferous data due to the prevalence of thick surficial deposits underlying the coniferous data. Of the known bedrock geology the sequence as ordination distance along axis 1 increases is from metasedimentary, sedimentary, metamorphic, volcanic, metavolcanic to schist/gness (Fig. 23). When age of the coniferous plots is plotted against standard deviation values for axis 1 age of plot increases as ordination distance increases. The more environmentally interpretable gradient for the coniferous data is axis 1. The variation along axis 2 is due in part to outlier type plots with varied development of understory species. As ordination distance along axis 2 increases cover and diversity of understory species decreases. In comparison to the deciduous and mixed deciduous-coniferous plots the variation in axis 2 is much less than the variation accounted for in axis 1.

Axis 1 for the deciduous and mixed deciduous-coniferous core group plot in the X-Y ordination plane (Fig. 16) also parallels a moisture gradient. The second axis shows high variation in standard deviation values also. When environmental values for the deciduous and mixed deciduous-coniferous plot data are plotted against standard deviation values for axis 1, the ordination distance can be interpreted as a trend from low elevation, flat, poorly drained areas to high elevation, well drained slopes (Figs. 24, 25, 26). The sequence in surficial geology as ordination distance increases along axis 1 is lacustrine, bedrock, eolian, glacial, alluvial/colluvial undifferentiated to alluvial deposits (Fig. 27).

Figure 22. The surficial geology of the coniferous plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the surficial geology as follows:

Ø = unknown

1 = glacial moraines

2 = recent moraines

3 = older moraines

4 = glacial/fluvial (undifferentiated)

5 = glacial outwash

6 = fluvial outwash

7 = alluvial/colluvial undifferentiated

8 = alluvial

9 = colluvial

10 = lacustrine deposits

11 = eolian deposits

12 = bedrock

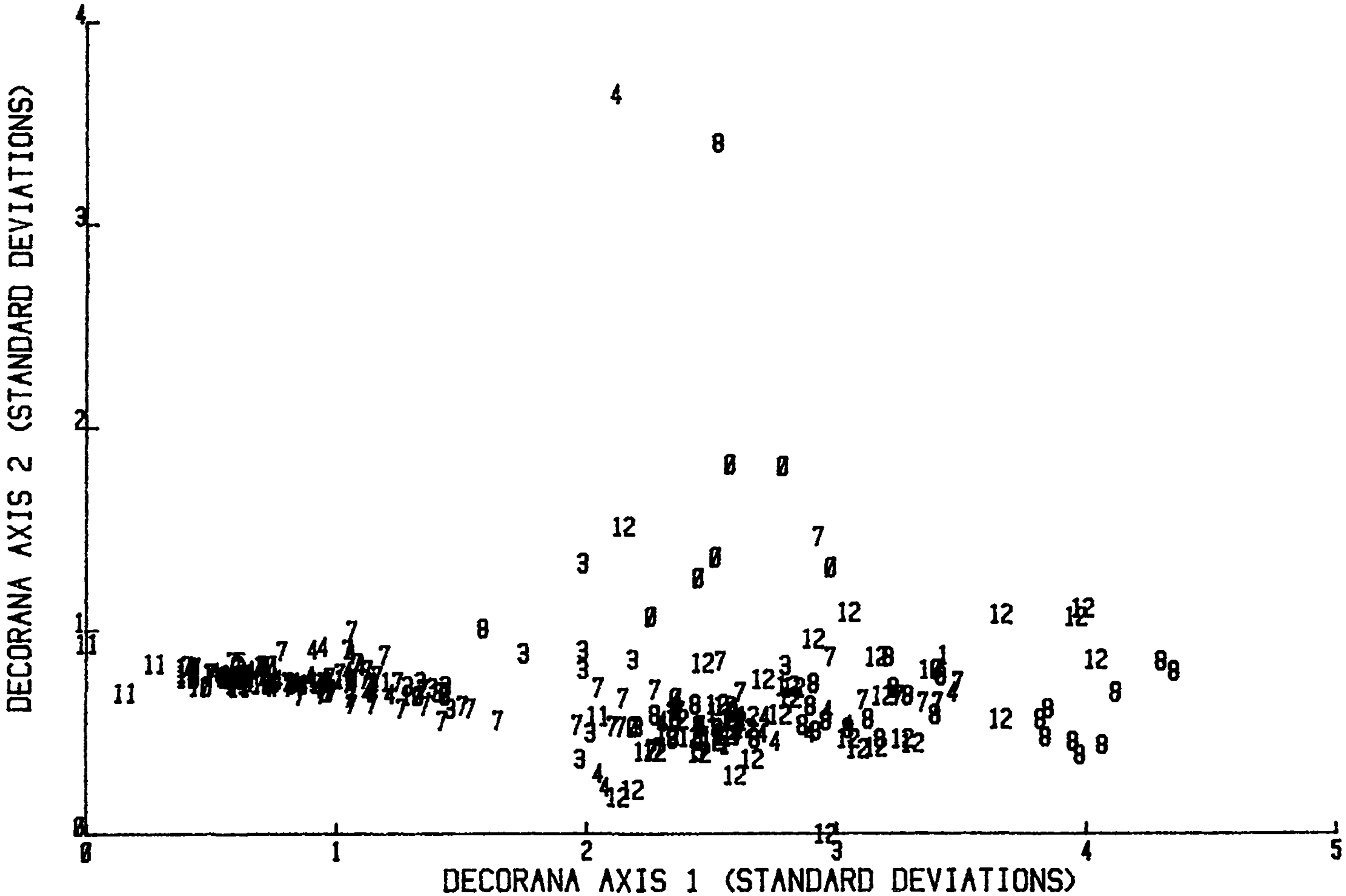

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 23. The bedrock geology of the coniferous plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the bedrock geology as follows:

Ø = unknown

1 = sedimentary

2 = metasedimentary

3 = volcanic

4 = metavolcanic

5 = basalt/gabbroic

6 = granite

7 = metamorphic

8 = schist/gneiss

9 = glacial ice/snow

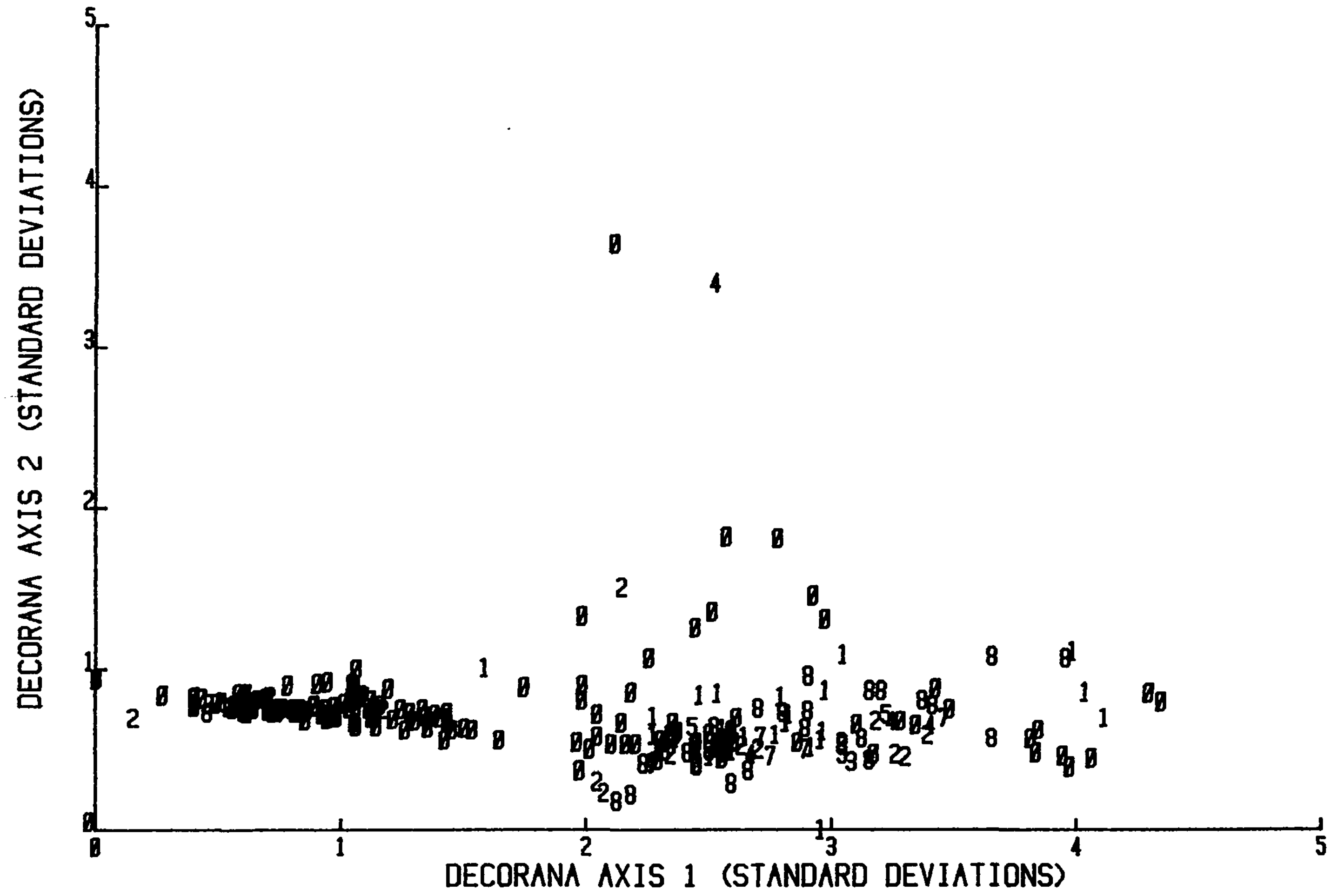

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 24. The elevation of the deciduous and mixed deciduous-coniferous plots along the first axis of variation of the DCA ordination. Elevation in meters (msl) is plotted against standard deviation values for the plots.

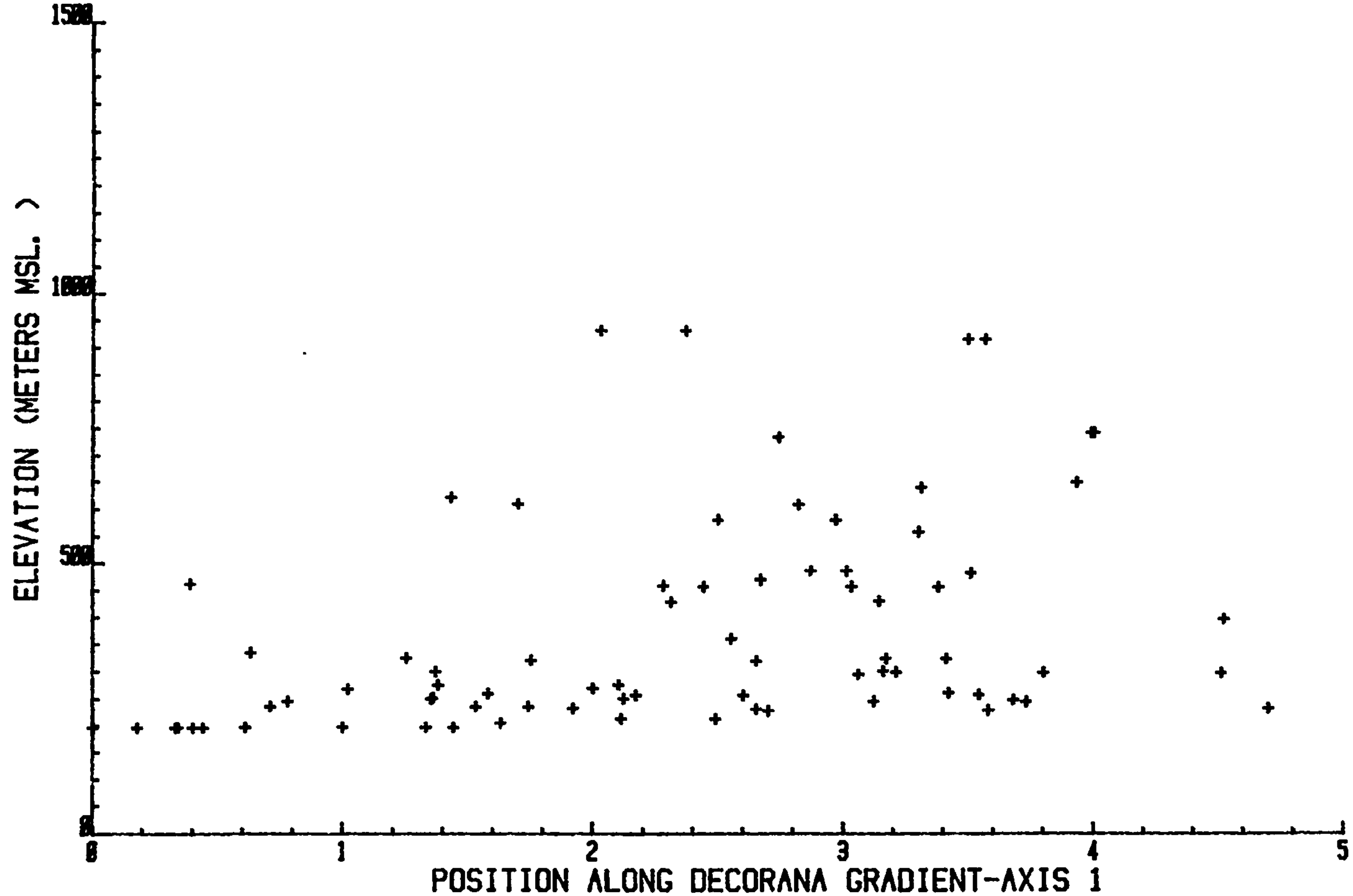
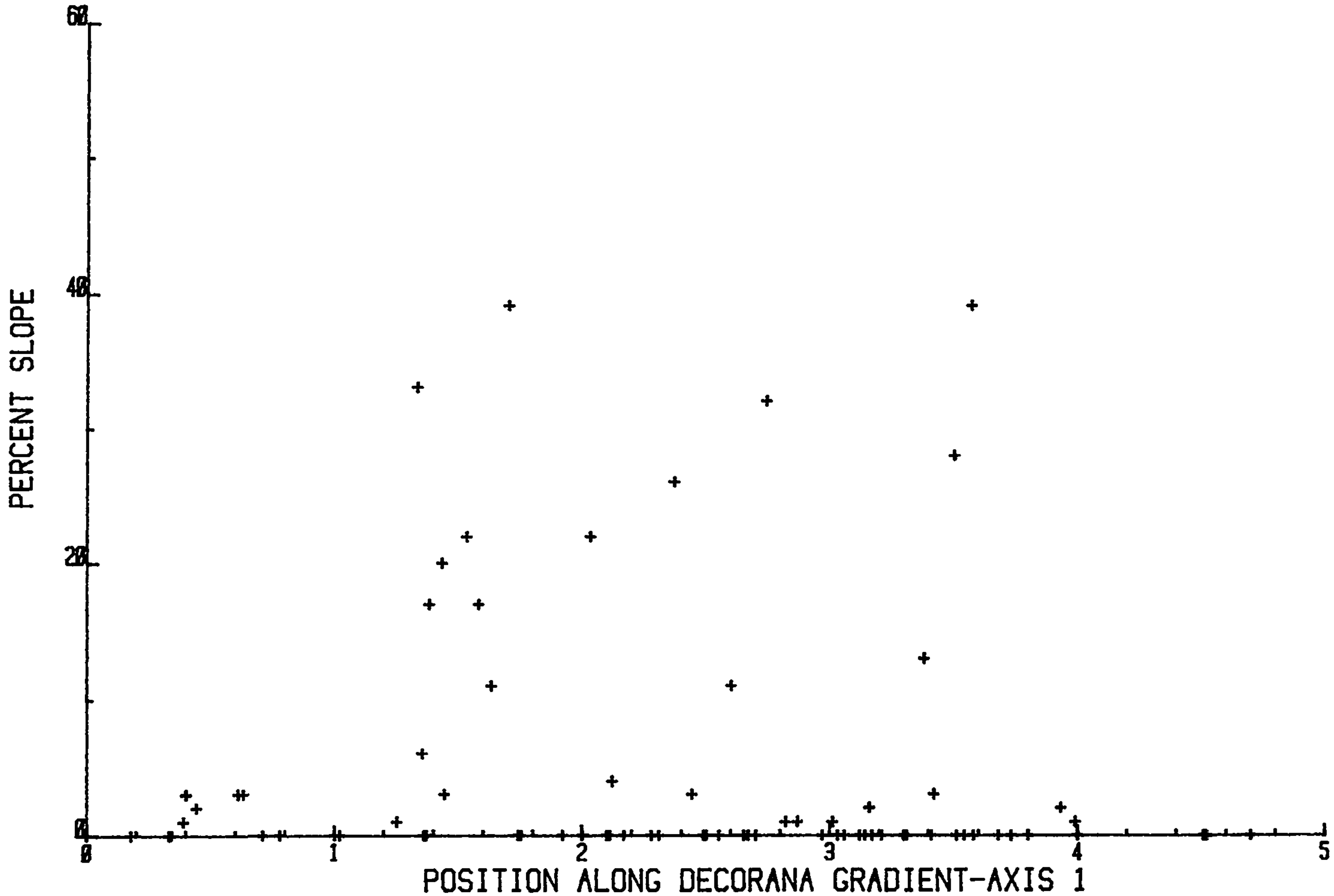

ELEVATION (METERS MSL.)
1500
1000
500
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 25. The percent slope of the deciduous and mixed deciduous-coniferous plots along the first axis of variation of the DCA ordination. The slope percent is plotted against standard deviation values for the plots.



60
40
20
0
PERCENT SLOPE
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 26. The position on the slope of the deciduous and mixed deciduous-coniferous plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions of the ordination axes are represented by numerical codes as follows:

1 = ridgetop

2 = upper half

3 = midslope

4 = lower half

5 = valley

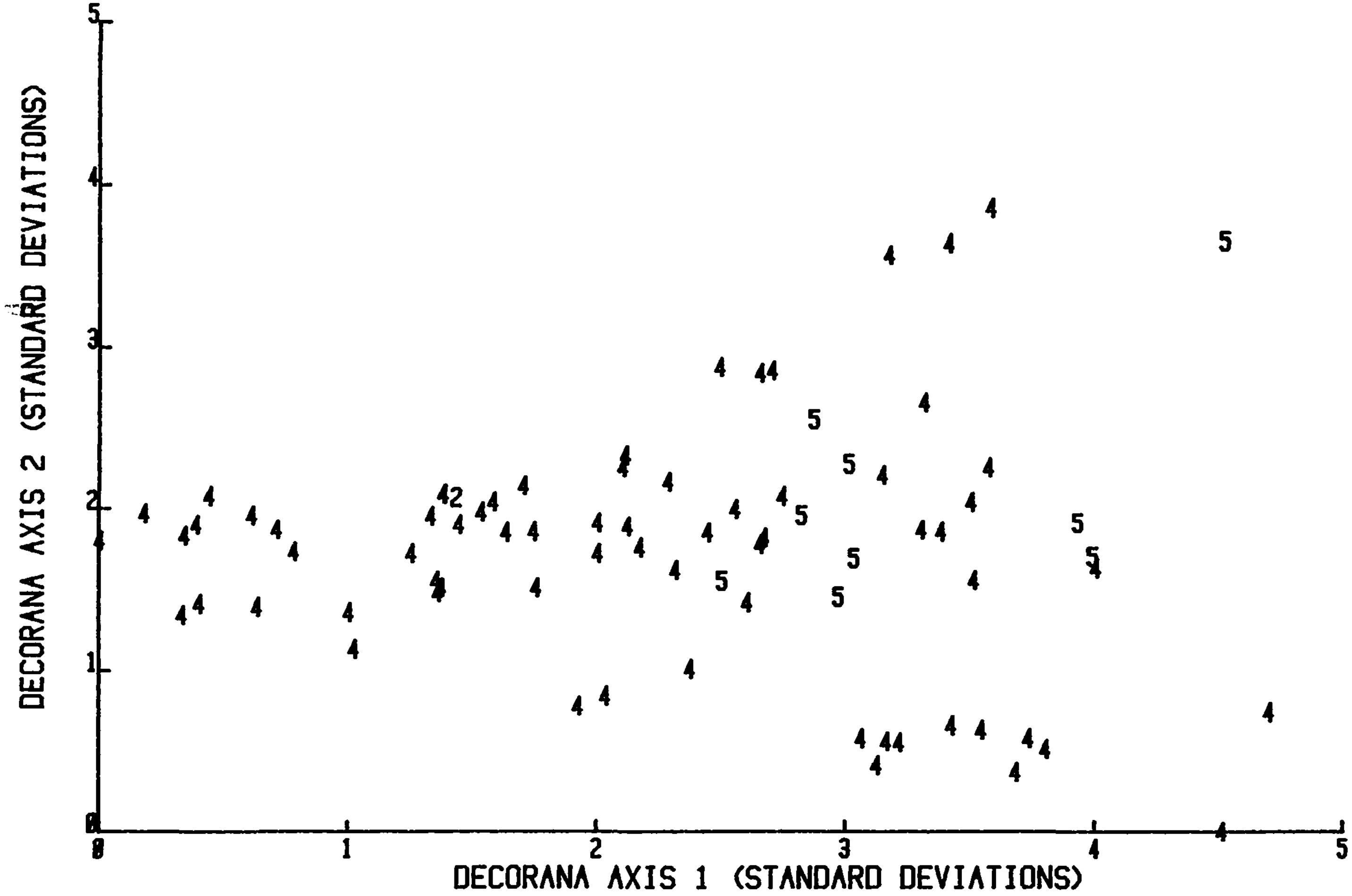

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 27. The surficial geology of the deciduous and mixed deciduous-coniferous plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the surficial geology as follows:

Ø = unknown

1 = glacial moraines

2 = recent moraines

3 = older moraines

4 = glacial/fluvial (undifferentiated)

5 = glacial outwash

6 = fluvial outwash

7 = alluvial/colluvial undifferentiated

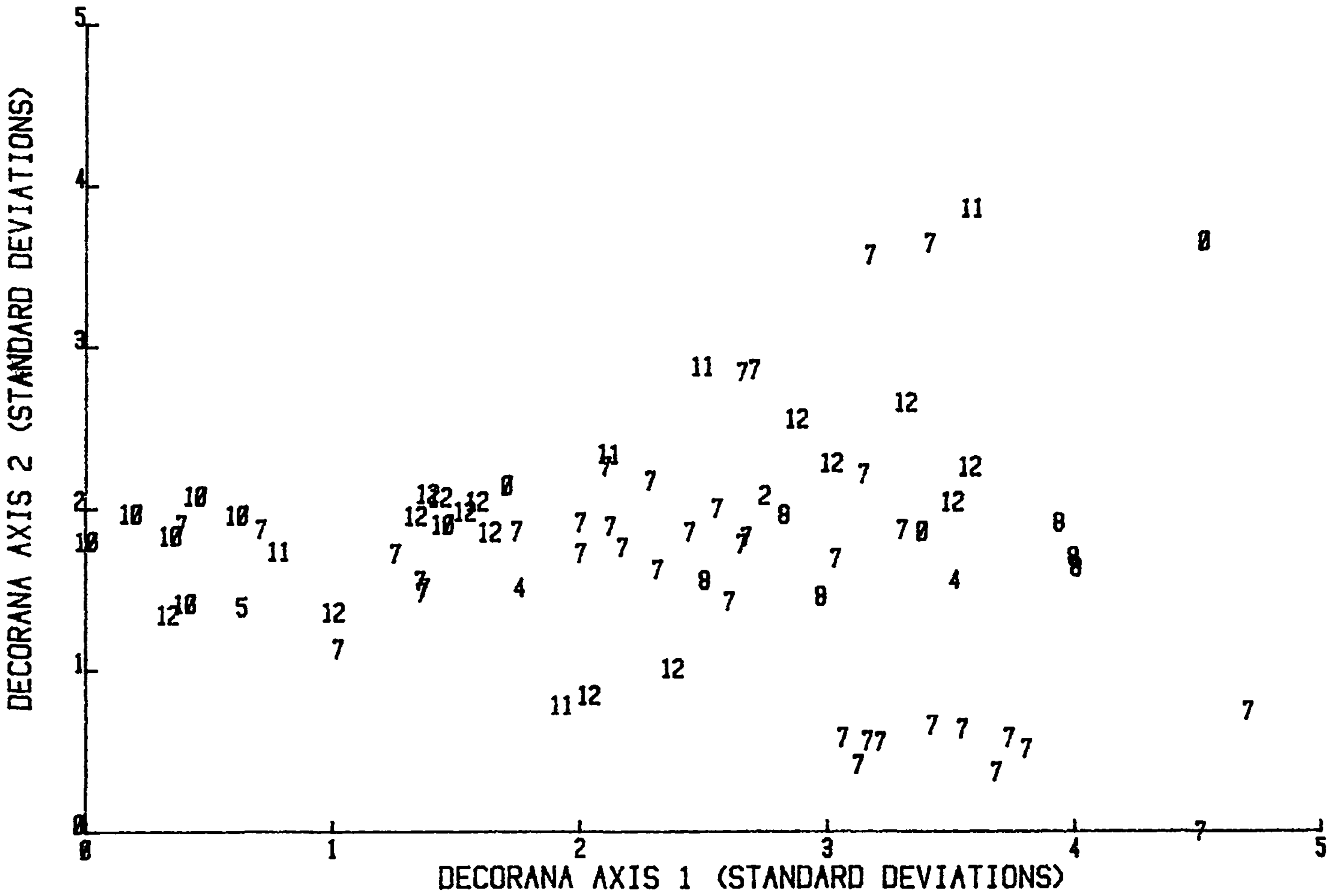
8 = alluvial

9 = colluvial

10 = lacustrine deposits

11 = eolian deposits

12 = bedrock


DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

The sequence in bedrock geology as ordination distance increases along axis 1 is schist/gneiss, metasedimentary, sedimentary, metavolcanic to volcanic (Fig. 28). The variation along axis 2 is due to a variable history of disturbance and succession in plots. An increase in ordination distance along axis 2 parallels an increase in disturbance from flooding and a subsequent poorer development of herbaceous and nonvascular layers. In addition to the variation attributable to floodplain succession is a variable history of fire in the plots. Core group M4 and M13 had BLM reported fires in 1972 and 1969, respectively (Buskirk, 1976). M4 showed an increased cover and complexity of herbaceous and nonvascular species which paralleled a low standard deviation value on axis 2.

Axis 1 for the shrub core group plot in the X-Y ordination plane (Fig. 17) also parallels a moisture gradient. The second axis shows high variation in standard deviation values. When environmental values for the shrub plot data are plotted against standard deviation values for axis 1 the ordination distance parallels the following gradients: low elevation to high elevation (Figs. 29, 30, 31), poorly drained with standing pools of water to well drained plots, slope aspects changing from northwest to southwest to southeast. The surficial geology sequence which parallels the ordination distance is glacial moraines, bedrock, glacial/fluvial, alluvial/colluvial, lacustrine to alluvial (Fig. 32). The bedrock geology sequence which parallels the ordination distance is metasedimentary, sedimentary, schist/gneiss, volcanic, metavolcanic to basalt/gabbroic (Fig. 33).

Figure 28. The bedrock geology of the deciduous and mixed deciduous-coniferous plots along the first two axes of the X-Y ordination plane of the ADC. The plot positions on the ordination axes are represented by numerical codes for the bedrock geology as follows:

Ø = unknown

1 = sedimentary

2 = metasedimentary

3 = volcanic

4 = metavolcanic

5 = basalt/gabbroic

6 = granite

7 = metamorphic

8 = schist/gneiss

9 = glacial ice/snow

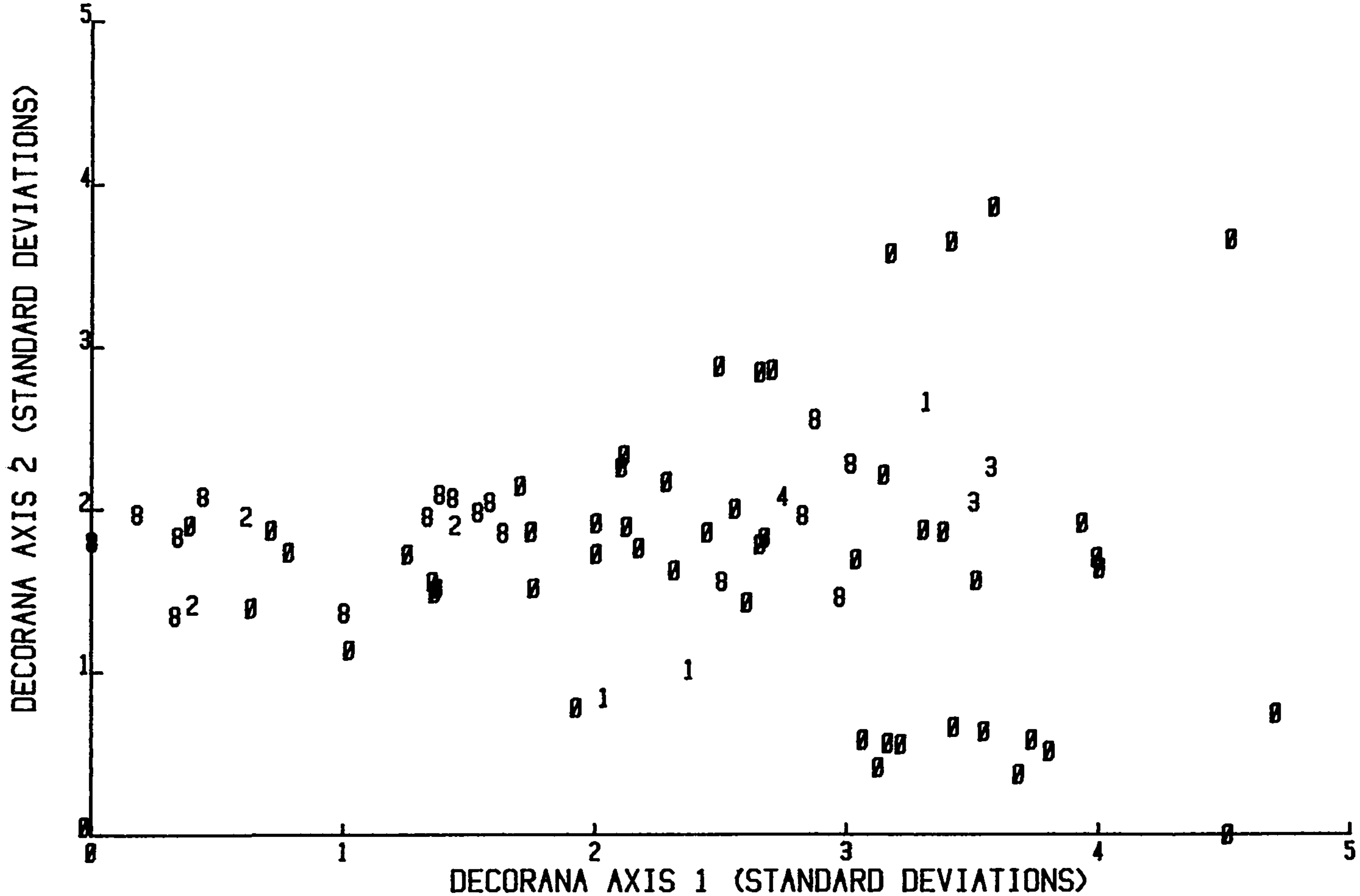

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

Figure 29. The elevation of the low and tall shrub plots along the first axis of variation of the DCA ordination. Elevation in meters (msl) is plotted against standard deviation values for the plots.

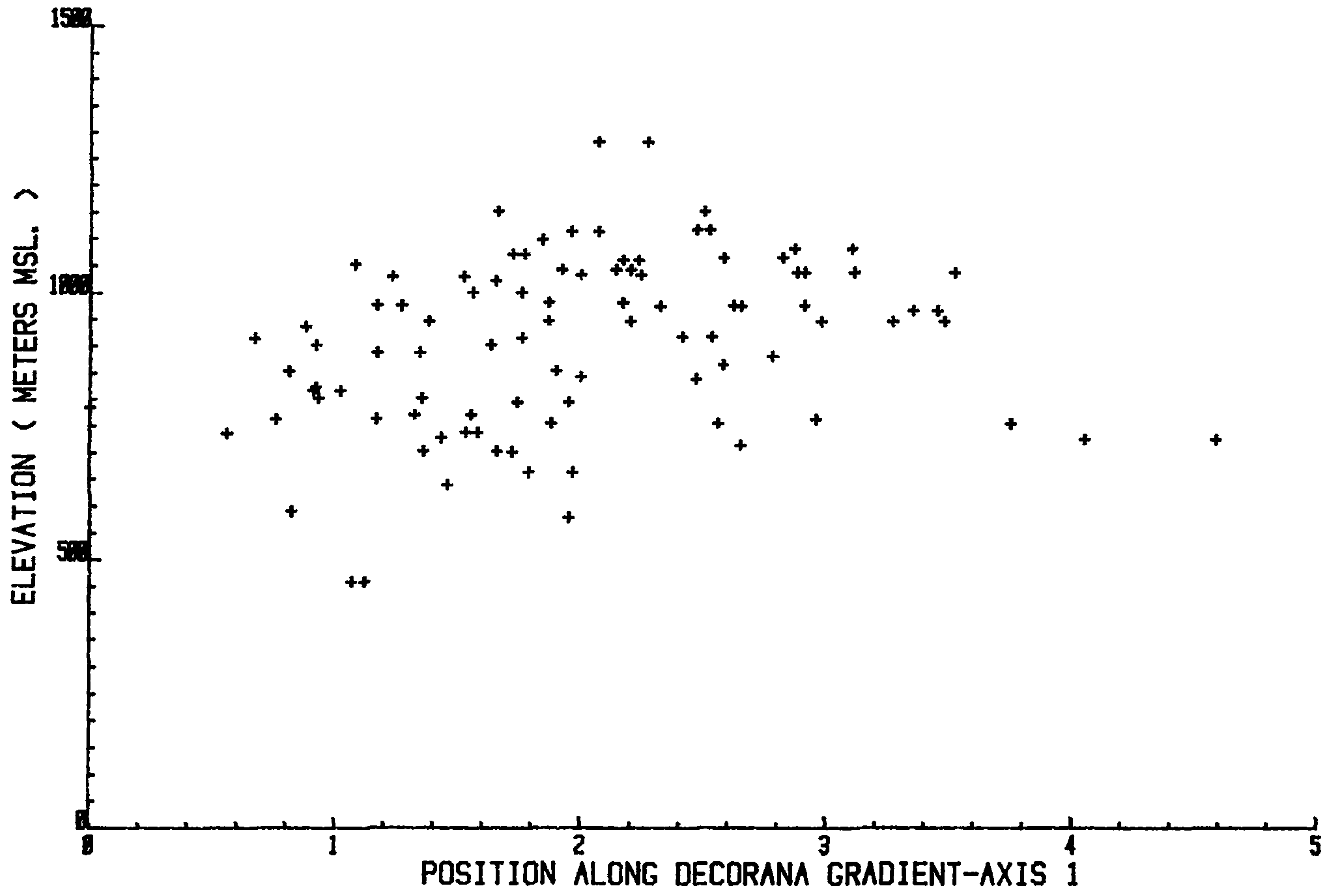

1500
1000
500
0
ELEVATION (METERS MSL.)
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 30. The percent slope of the low and tall shrub plots along the first axis of variation of the DCA ordination. The slope percent is plotted against standard deviation values for the plots.

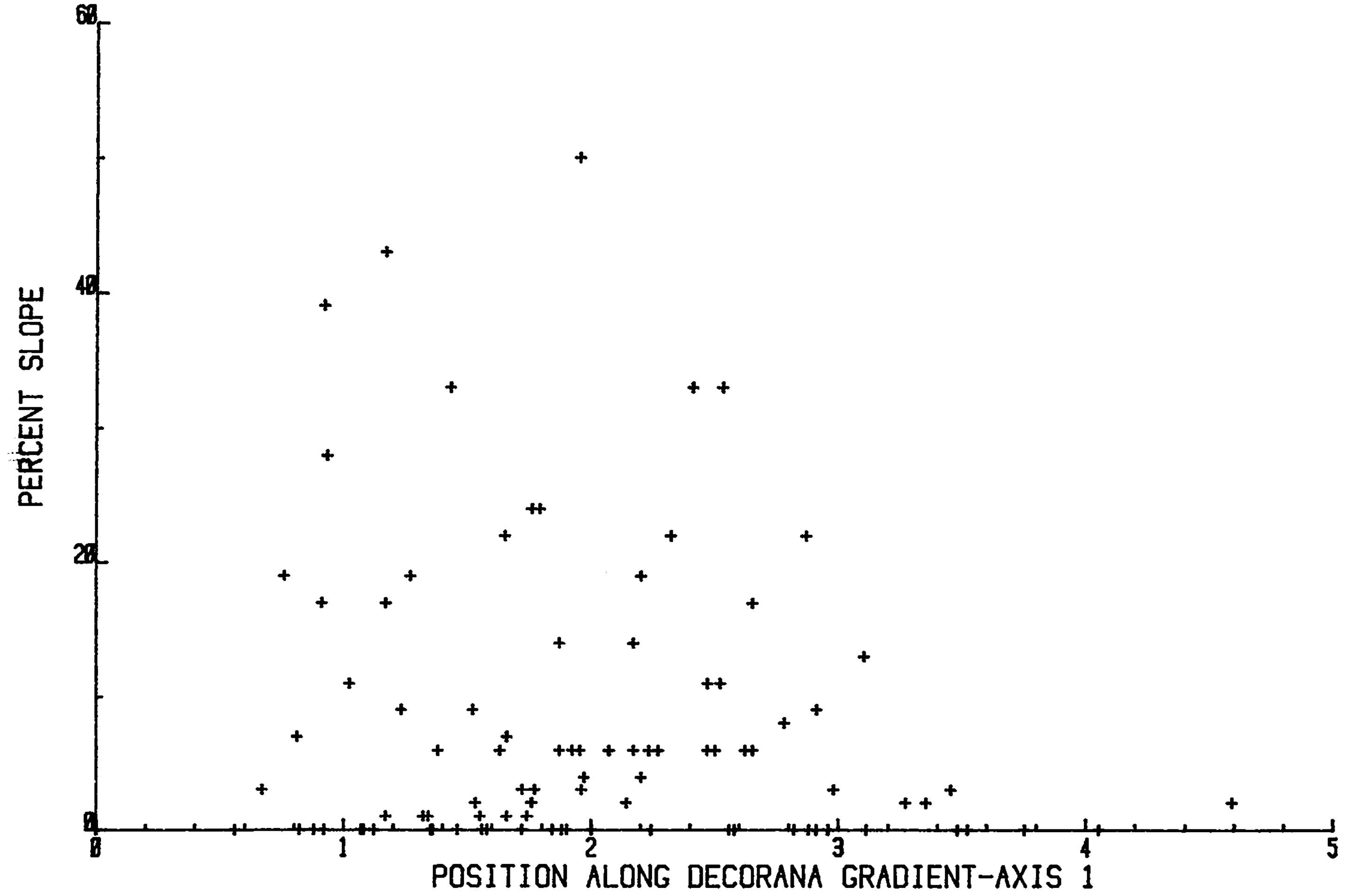

PERCENT SLOPE
60
40
20
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 31. The position on the slope of the low and tall shrub plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes as follows:

1 = ridgetop

2 = upper half

3 = midslope

4 = lower half

5 = valley

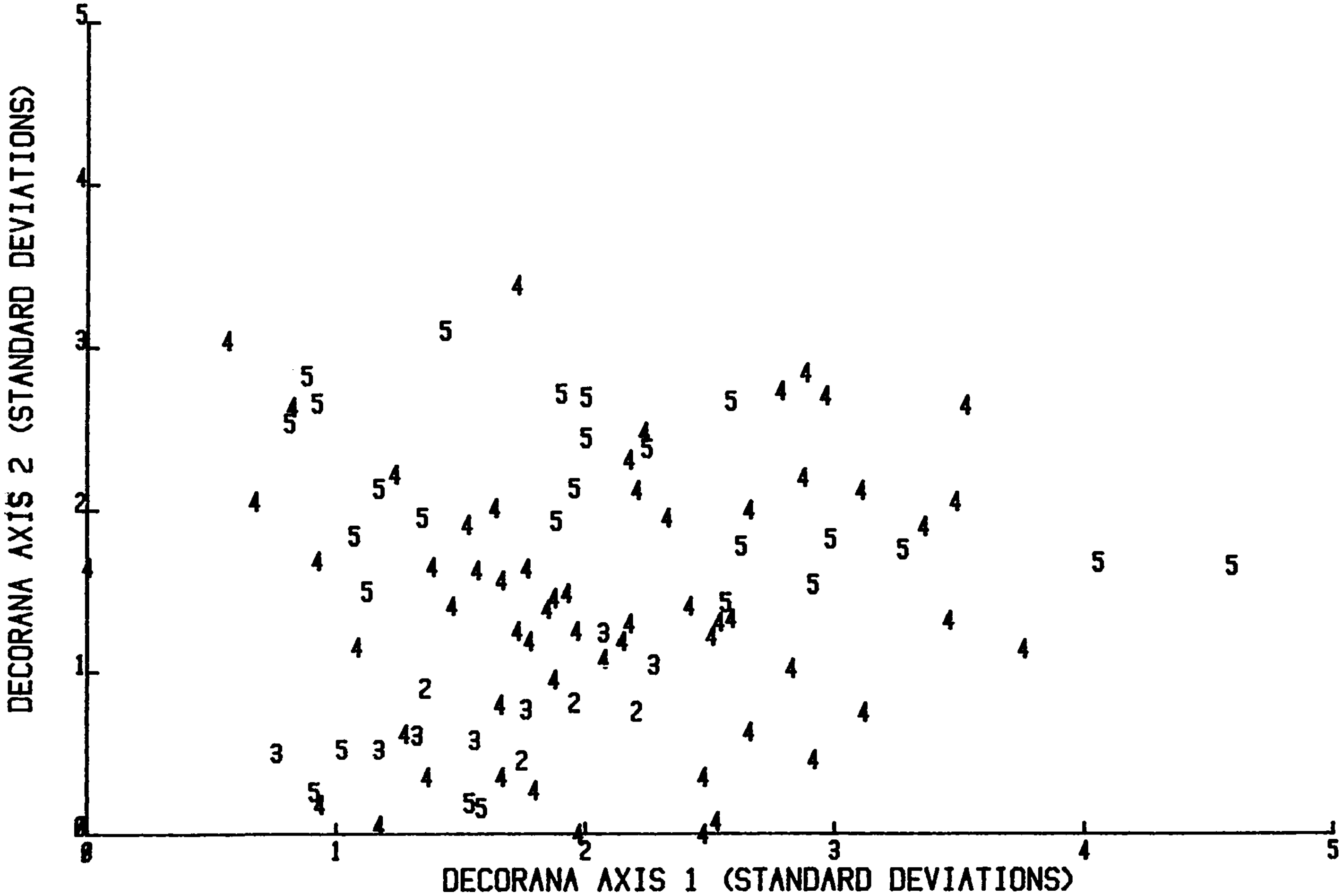

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 32. The surficial geology of the low and tall shrub plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the surficial geology as follows:

Ø = unknown

1 = glacial moraines

2 = recent moraines

3 = older moraines

4 = glacial/fluvial (undifferentiated)

5 = glacial outwash

6 = fluvial outwash

7 = alluvial/colluvial (undifferentiated)

8 = alluvial

9 = colluvial

10 = lacustrine deposits

11 = eolian deposits

12 = bedrock

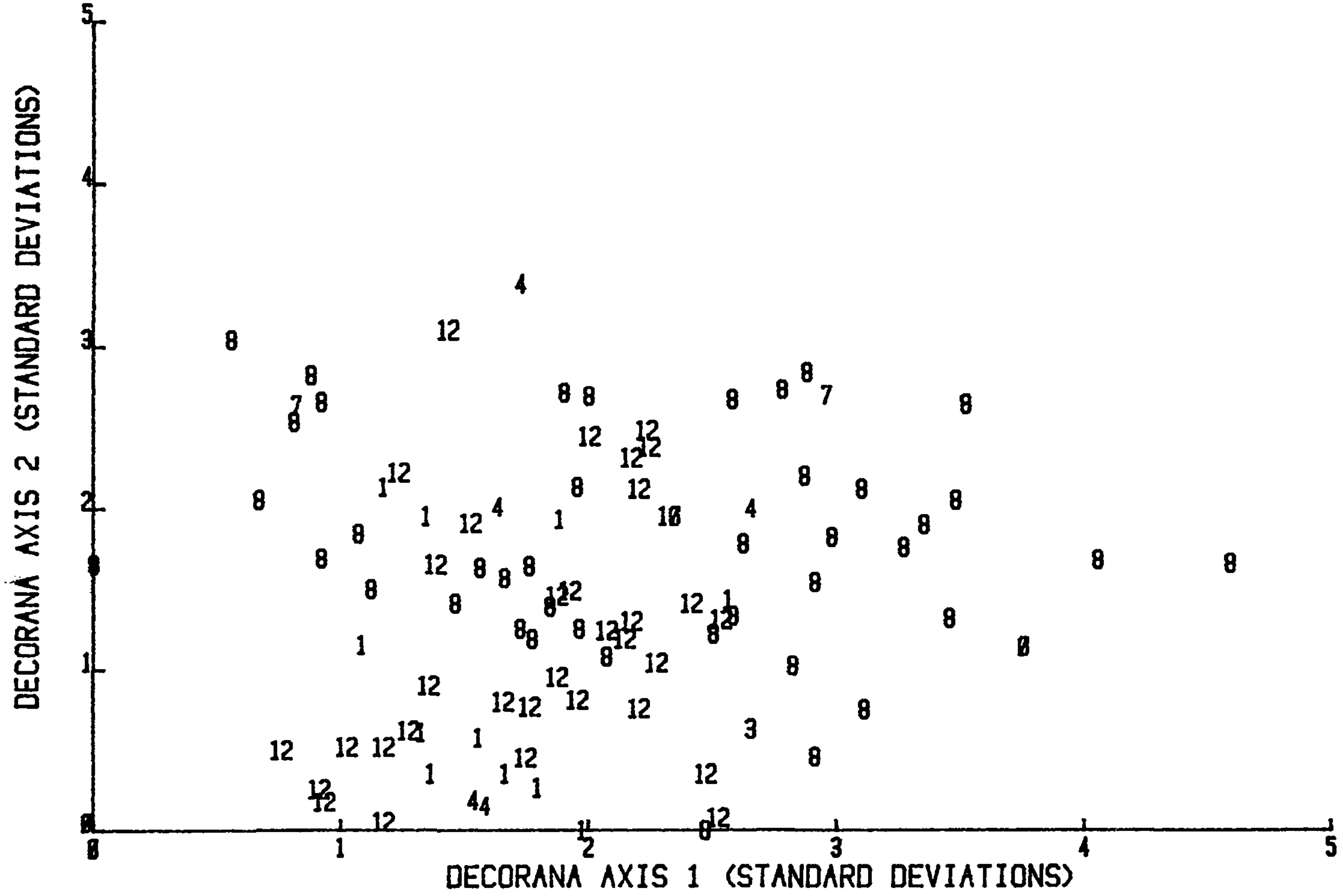

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

Figure 33. The bedrock geology of the low and tall shrub plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the bedrock geology as follows:

Ø = unknown

1 = sedimentary

2 = metasedimentary

3 = volcanic

4 = metavolcanic

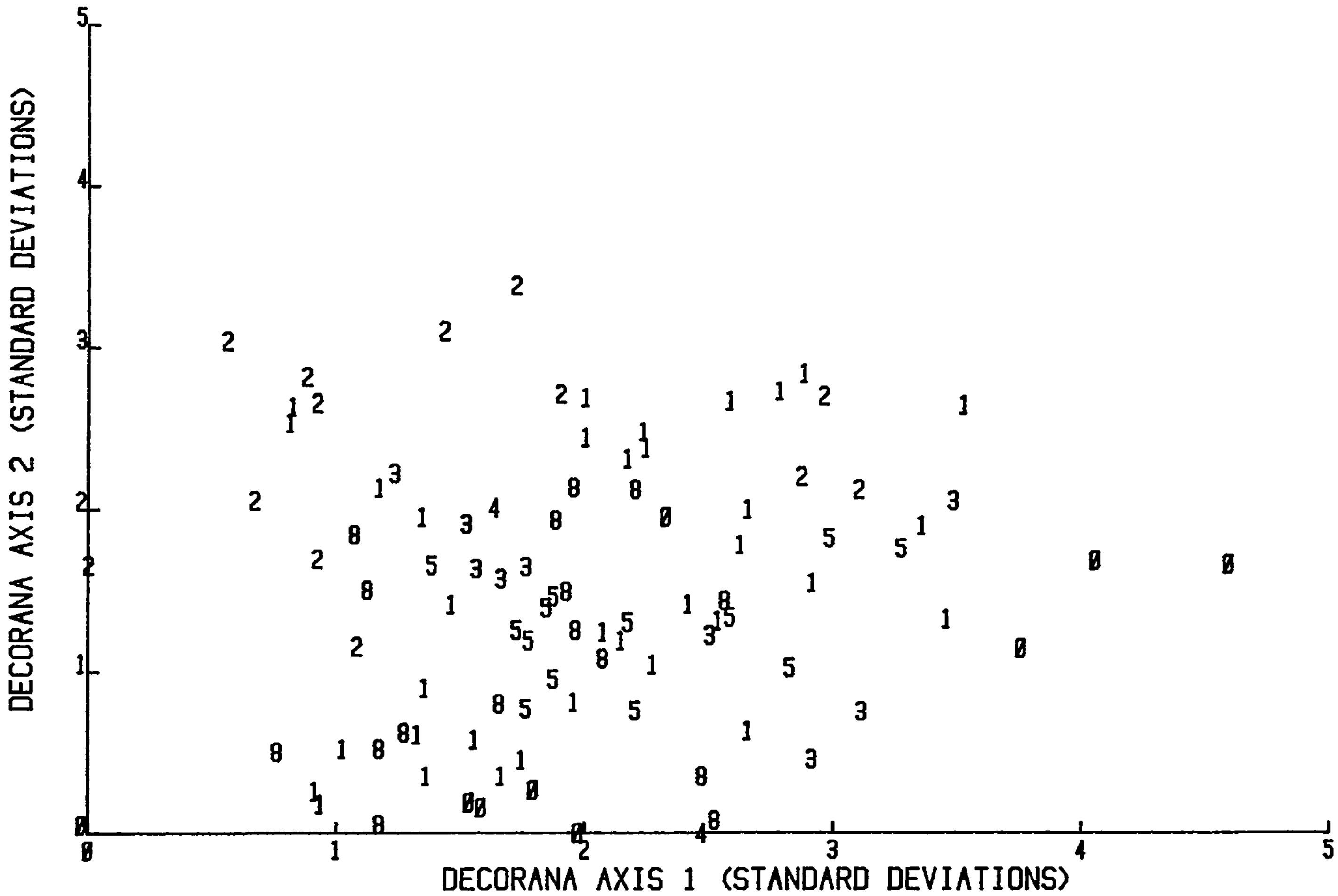
5 = basalt/gabbroic

6 = granite

7 = metamorphic

8 = schist/gneiss

9 = glacial ice/snow


DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

The variation along axis 2 is related to a variation in diversity of species. As ordination distance increases diversity of shrub, herbaceous and nonvascular layers decreases. This is also reflected in the decrease in structural complexity of stratal layers. The percent of ground surface unvegetated also decreases. This variation is caused by floodplain succession and seasonal flooding.

When tundra core groups are plotted on the X-Y ordination plane axis 1 parallels a moisture gradient from dry to wet as ordination distance increases (Fig. 18). When environmental values for the tundra plot data are plotted against standard deviation values for axis 1, the ordination distance can be interpreted as a trend from high elevation upper slopes and ridgetops to lower elevation flatter areas on the lower half of the slope (Figs. 34, 35, 36). The sequence of surficial geology types as ordination distance increases is bedrock, older moraines, glacial moraines to alluvial (Fig. 37). The sequence of bedrock geology types as ordination distance increases is basalt/gabbroic, metasedimentary, volcanic, schist/gneiss to sedimentary (Fig. 38).

The variation along axis 2 for the tundra plots is related to a variation in diversity of shrub and herbaceous layers. As ordination distance increases diversity and percent of ground surface vegetated increases. Structural complexity of stratal layers also increases. Percent of ground surface vegetated also increases as ordination distance increases along axis 1. This variation in diversity of species and percent ground cover vegetated is a function of altitude and stability of slope.

Figure 34. The elevation of the dwarf shrub and shrub tundra plots along the first axis of variation of the DCA ordination. Elevation in meters (msl) is plotted against standard deviation values for the plots.

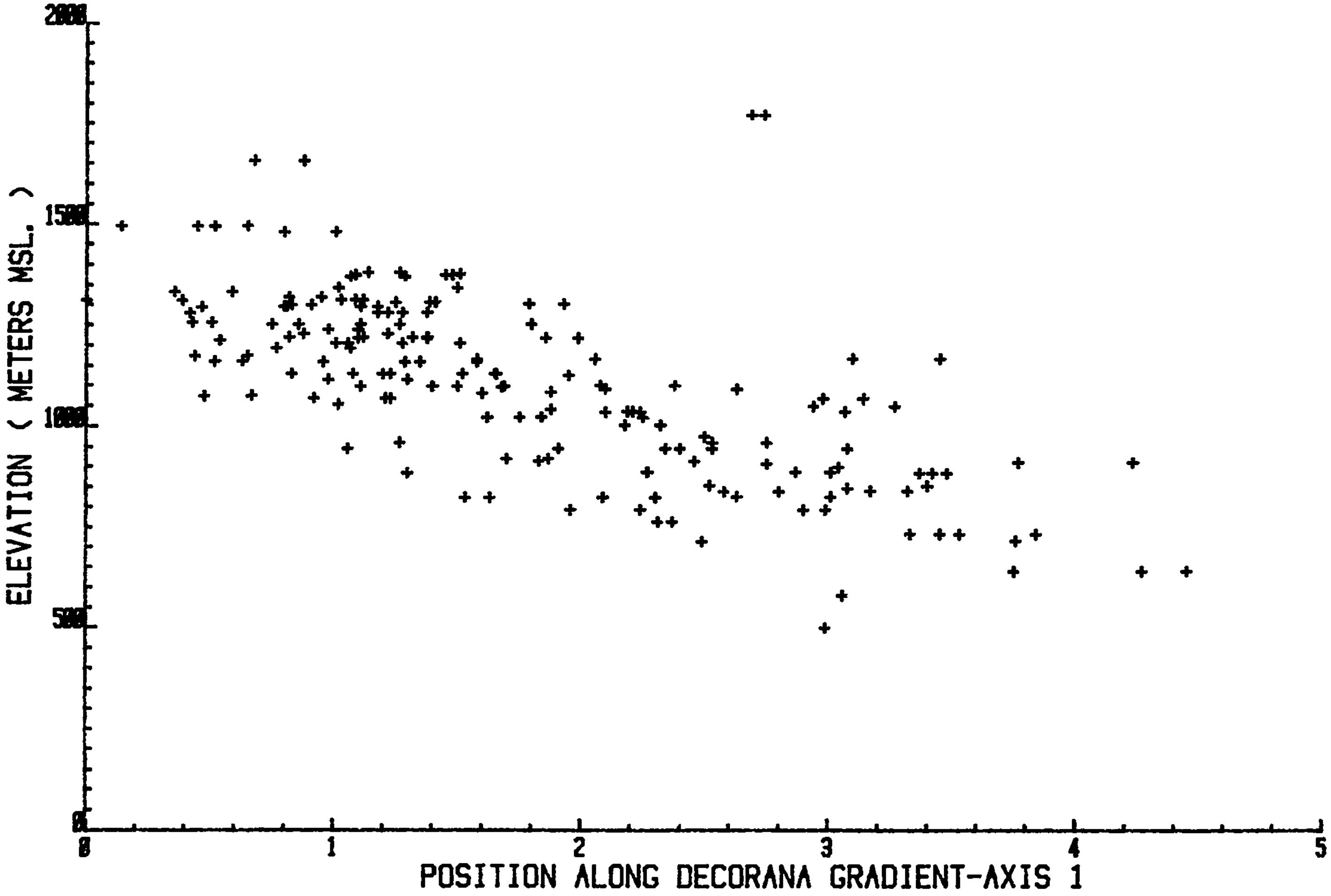
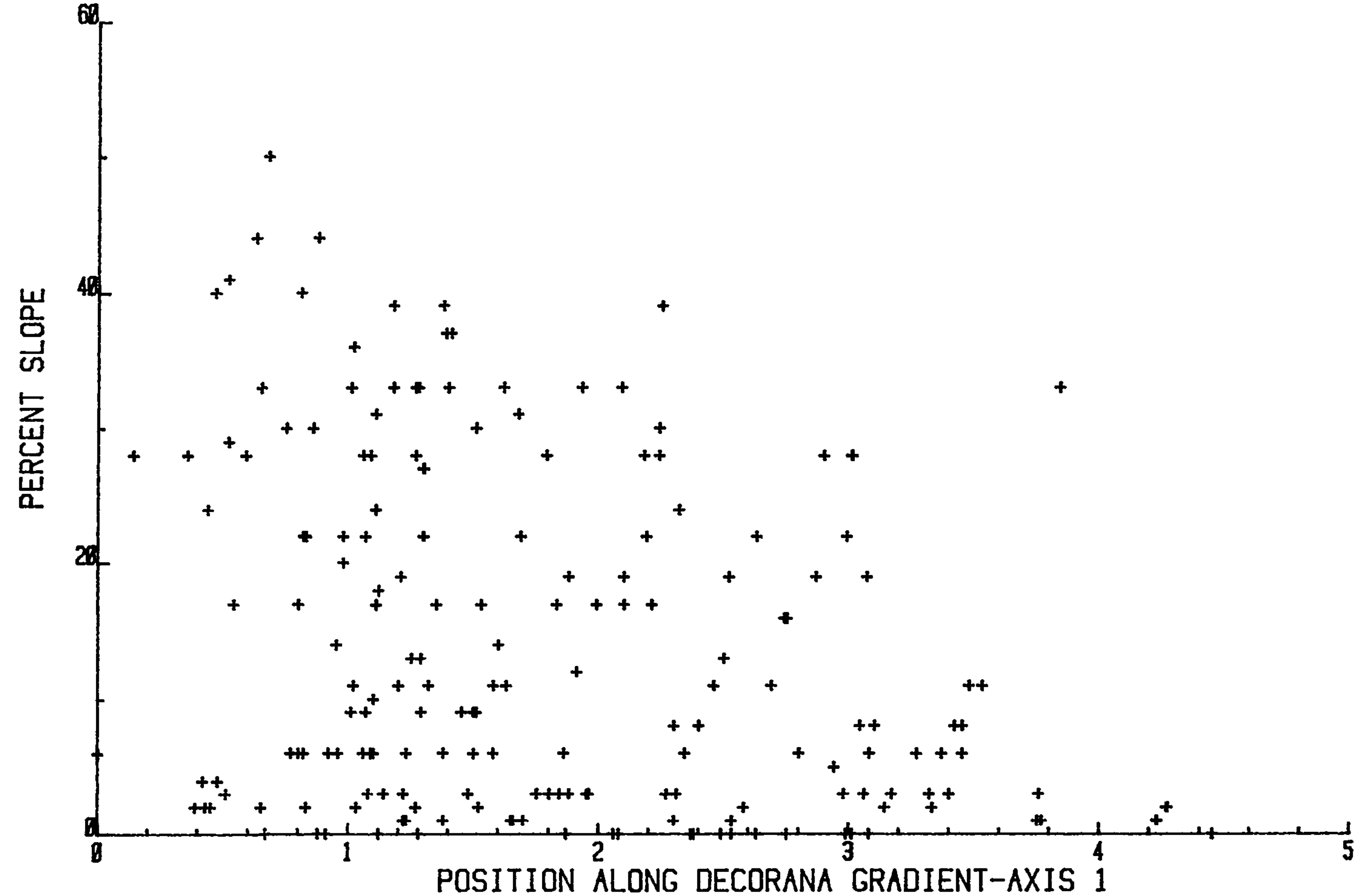

ELEVATION (METERS MSL.)
2000
1500
1000
500
0
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 35. The percent slope of the dwarf shrub and shrub tundra plots along the first axis of variation of the DCA ordination. The slope percent is plotted against standard deviation values for the plots.



60
40
20
0
PERCENT SLOPE
0
1
2
3
4
5
POSITION ALONG DECORANA GRADIENT-AXIS 1

Figure 36. The position on the slope of the dwarf shrub and shrub tundra plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes as follows:

1 = ridgetop

2 = upper half

3 = midslope

4 = lower half

5 = valley

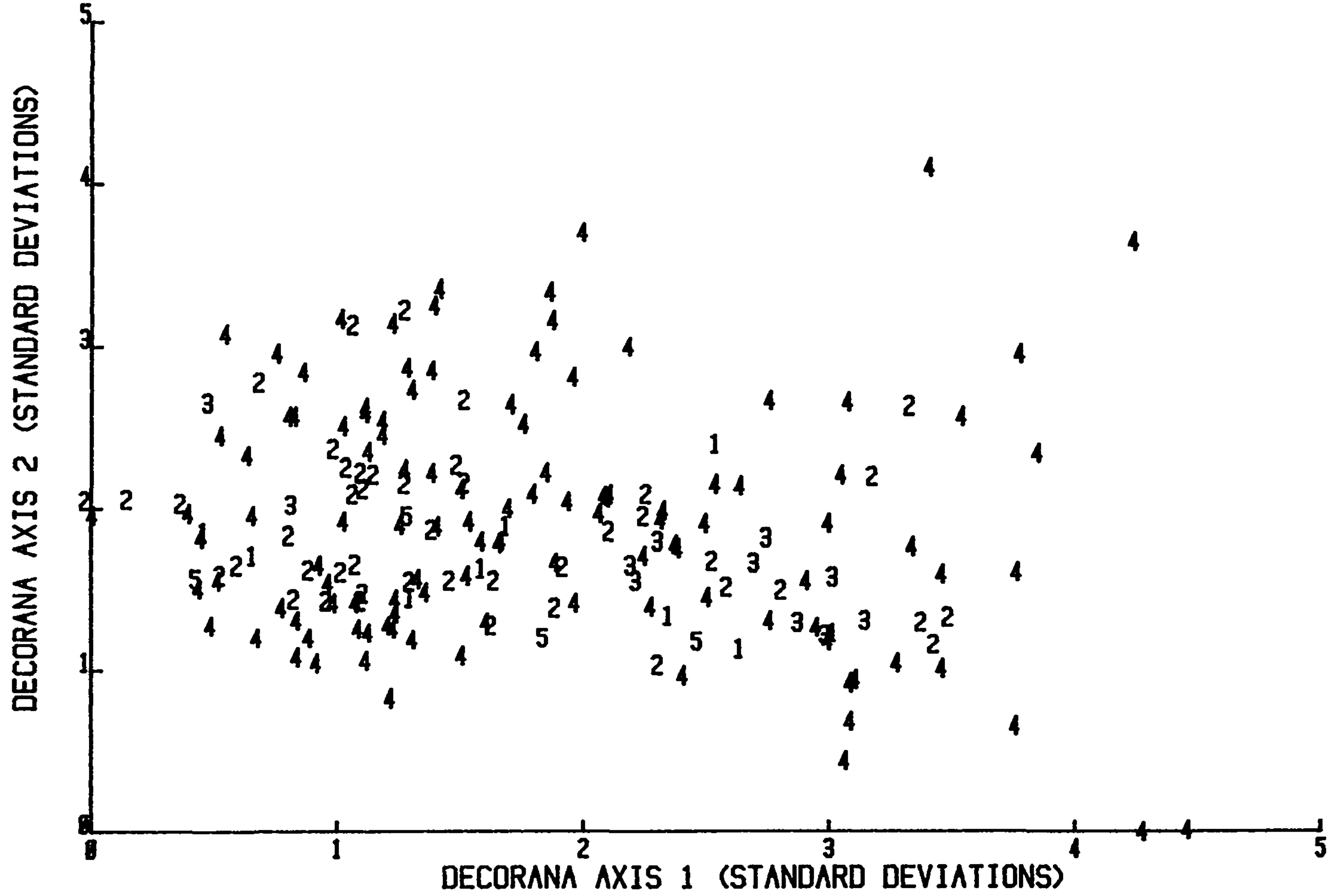

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 37. The surficial geology of the dwarf shrub and shrub tundra plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the surficial geology as follows:

Ø = unknown

1 = glacial moraines

2 = recent moraines

3 = older moraines

4 = glacial/fluvial (undifferentiated)

5 = glacial outwash

6 = fluvial outwash

7 = alluvial/colluvial undifferentiated

8 = alluvial

9 = colluvial

10 = lacustrine deposits

11 = eolian deposits

12 = bedrock

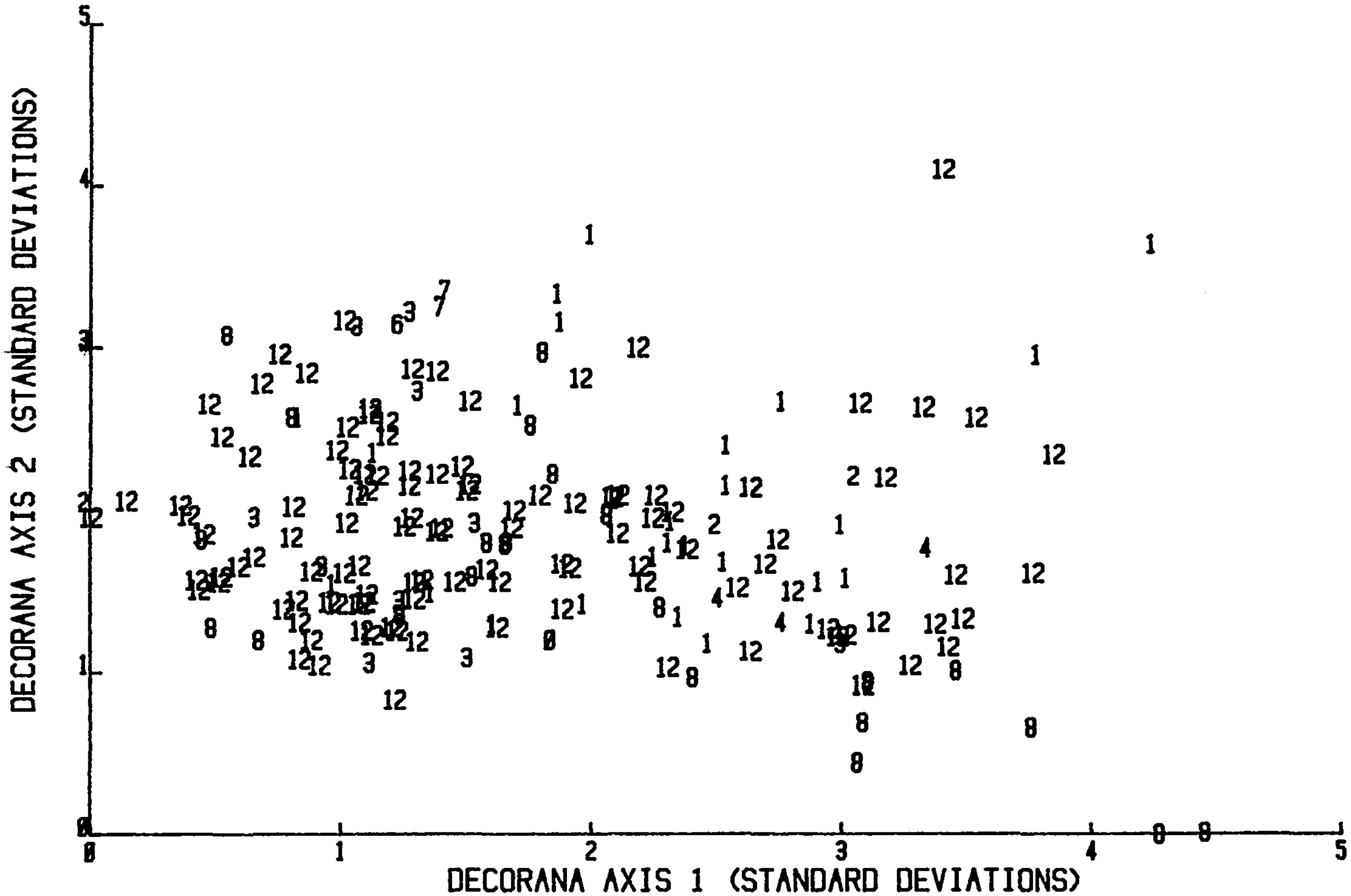

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 38. The bedrock geology of the dwarf shrub and shrub tundra plots along the first two axes of the X-Y ordination plane of the DCA. The plot positions on the ordination axes are represented by numerical codes for the bedrock geology as follows:

Ø = unknown

1 = sedimentary

2 = metasedimentary

3 = volcanic

4 = metavolcanic

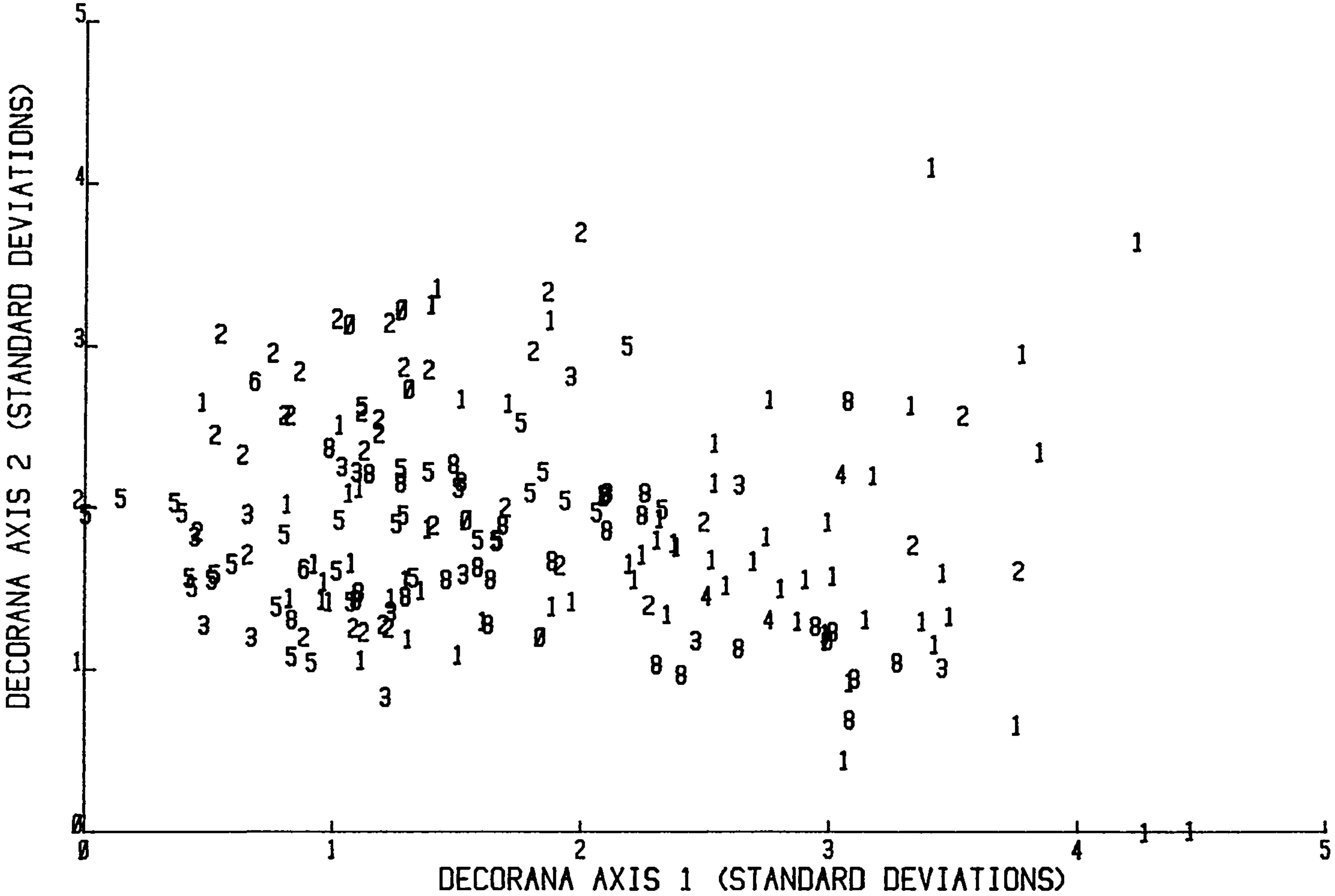
5 = basalt/gabbroic

6 = granite

7 = metamorphic

8 = schist/gneiss

9 = glacial ice/snow


DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Summary of Core Groups

A description of the 59 core groups as represented in the data is on the following pages. The following summary is based on the 59 core groups identified by TWISA of the data set divided into four matrices.

This is a specialized classification and description intended to apply to the study area. It has been constructed to permit comparison with that of Dyrness and Viereck (1980).

Coniferous Forest

Picea mariana - Larix laricina

C1 *Larix laricina, Picea mariana, Andromeda polifolia, Eriophorum vaginatum, Sphagnum* spp.

The average overstory cover of this community is 10 to 15%, predominately composed of *Larix laricina*. *Picea mariana* is associated. This is an early successional type of wet areas with an average stand age of 74 years. The ground surface is hummocky, being too wet to form tussocks. *Andromeda polifolia* is the dominant shrub with an average cover of 50-75%. *Betula nana, Ledum palustre* and *Chamaedaphne calyculata* are associated all with an average cover of 10%. *Salix fuscescens* and *Vaccinium uliginosum* are rare associates.

The herbaceous layer is dominated by *Eriophorum vaginatum* or *Equisetum fluviatile* with an average cover of 80%. Other herbs include *Drosera rotundifolia, Carex rhynchophysa, Sparangium angustifolium, Menyanthes trifoliata* and *Potentilla palustris*. The nonvascular cover is 80% composed solely of *Sphagnum* spp.

This community is found in the Tanana lowland on eolian deposits at an average altitude of 217 m (elevation range is 198 to 236 m).

C2 *Picea mariana-Larix laricina, Ledum palustre, Empetrum nigrum, Sphagnum* spp.

This community has an overstory closure of 20% codominated by *Picea mariana* and *Larix laricina* with an average age of 145 years. The shrub layer, with an average cover of 60%, is composed of *Ledum palustre, Betula nana* and *Vaccinium uliginosum* with covers of 30, 10 and 20% respectively. *Salix glauca* and *S. planifolia* ssp. *pulchra* occur occasionally. The herbaceous cover is 75%. *Empetrum nigrum* (60% cover) is the most abundant herb. *Rubus chamaemorus, Oxycoccus microcarpus, Vaccinium vitis-idaea, Carex bigelowii* each have 15% cover. *Sphagnum* spp. is dominant in the nonvascular layer with 70% cover. *Cladonia rangiferina* (20% cover), *Cladonia alpestris, Cladonia* spp., *Cetraria* spp. and *Polytrichium strictum* also add to the nonvascular layer.

This type is found on a glacial/fluvial or alluvial/colluvial substrate at an average altitude of 460 m in the Tanana lowland (elevation range is 329 to 506 m).

C3 *Picea mariana, Larix laricina, Ledum palustre, Eriophorum vaginatum, Sphagnum* spp.

The overstory of this community is dominated by *Picea mariana* with a cover of 20%. *Larix laricina* is occasionally associated and is generally older than the *Picea*. No *Larix* seedlings are present. The average age of this type is 123 years. *Ledum palustre* is the dominant shrub with 30% cover. *Vaccinium uliginosum, Betula nana* and *Andromeda polifolia* have cover values of 15, 10 and 5% respectively. *Eriophorum vaginatum* forms tussocks 30 cm high and has a cover of 70%. *Vaccinium vitis-idaea, Empetrum nigrum, Oxycoccus microcarpus* and *Rubus chamaemorus* are also frequent with cover values of 25, 10, 10, and 10% respectively.

Sphagnum spp. dominates the nonvascular layer with a cover of 50%. *Cladonia rangiferina* (20% cover), *Cladonia alpestris* (5% cover), *Cetraria cucullata, Nephroma arcticum* and *Pleurozium schreberi* (5% cover) and *Tomenthypnum nitens* also compose the nonvascular layer.

C3 is found at an average altitude of 288 m in the Tanana lowland with plots at altitudes ranging from 198 to 572 m.

In comparison to C2 this type is of younger age, contains less *Larix*, more *Eriophorum*, no *Salix* spp. and is of lower altitude. C3 is found most commonly on eolian or lacustrine substrates but also occurs on glacial/fluvial and alluvial/colluvial.

C4 *Picea mariana-Larix laricina, Betula nana, Ledum palustre, Vaccinium uliginosum, Vaccinium vitis-idaea, Carex bigelowii, Sphagnum* spp.

Picea mariana and *Larix laricina* are codominant and compose an overstory cover of 20%. *Picea* are the oldest trees, and the average age of this type is 194 years. Both *Larix* and *Picea* seedlings occur. The shrub stratum has a cover of 65% composed of *Betula nana* (25% cover), *Salix planifolia* ssp. *pulchra* (5% cover), *Ledum palustre* (30% cover) and *Vaccinium uliginosum* (25% cover). *Chamaedaphne calyculata, Alnus crispa* and *Spirea beauverdiana* are occasional associates.

Empetrum nigrum, Carex bigelowii and *Vaccinium vitis-idaea* each have 25% cover in the herbaceous stratum. *Equisetum silvaticum* and *Rubus chamaemorus* have 10% cover values. *Arctagrostis latifolia* var. *arundinacea* and *Eriophorum vaginatum* ssp. *vaginatum* are occasional associates. *Sphagnum* spp., *Pleurozium schreberi, Polytrichium strictum, Nephroma arcticum* and *Cladonia rangiferina* have 75, 10, 10, 5 and 10% cover values respectively in the nonvascular layer.

This type C4 is found in the Tanana lowland at an average altitude of 309 m. It most commonly occurs on alluvial/colluvial deposits (46%) but may also occur on glacial/fluvial substrates (26%), older moraines (17%), eolian deposits (5%) or lacustrine deposits (5%). The average slope is 2% with an exposure of 195°. The slope ranges from 0 to 6%. The elevation of plots ranges from 198 to 479 m, and the mean elevation is 309 m.

C5 *Picea mariana-Larix laricina, Ledum palustre, Vaccinium uliginosum, Rubus chamaemorus*, feathermoss

Picea mariana and *Larix laricina* are codominant in the overstory of this community with a cumulative cover of 20%. The seedlings are predominately *Picea mariana* and the average age is 186 years. The 65% shrub layer cover is contributed by *Ledum palustre* ssp. *groenlandicum* (30%), *Vaccinium uliginosum* (25%), *Salix planifolia* ssp. *pulchra* (5%), *Salix lanata* ssp. *richardsonii* (5%), and *Betula glandulosa* (5%). The herbaceous layer is composed of *Rubus chamaemorus, Vaccinium vitis-idaea, Empetrum nigrum, Arctagrostis latifolia* var. *arundinacea, Carex bigelowii,* *Equisetum arvense, Arctostaphylos alpina, Eriophorum vaginatum* and *Oxycoccus microcarpus*. The first three species each contribute 10% to the herbaceous cover. The remaining species contribute 5% to the cover value.

The feathermosses *Pleurozium schreberi, Hylocomium splendens* and *Aulacomnium* spp. contribute 45% to the nonvascular cover and *Sphagnum* spp. contributes 5%. *Cladonia rangiferina* (30%), *Cladonia multiformis, Cladonia* spp. and *Peltigera aphthosa* var. *leucoplebia* are also contributing nonvascular species.

This type is found in the Tanana lowland at an average altitude of 261 m on alluvial/colluvial deposits. The range in elevation is 198 to 317 m. *Sphagnum* spp. have less cover value, and the *Larix* seedlings and *Alnus crispa* are absent as compared to C4.

Picea glauca

C6 *Picea glauca, Betula glandulosa, Vaccinium vitis-idaea, Empetrum nigrum*, feathermoss

This is an open *Picea glauca* community (15-20% cover); *Picea mariana* was an occasional associate. The mean age of this type is 172 years. *Betula glandulosa* is the dominant shrub with 60% cover. *Ledum palustre, Vaccinium uliginosum* and *Salix planifolia* ssp. *pulchra* contribute 10, 10 and 5% to the shrub layer respectively. The herbaceous layer is composed of *Empetrum nigrum* (25% cover), *Vaccinium vitis-idaea* (25% cover), *Aster sibiricus* and *Lycopodium annotinum* var. *pungens*. The major species of the nonvascular layer are *Hylocomium splendens*

(50%), *Pleurozium shreberi* (30%), *Peltigera aphthosa* var. *leucoplebia* (5%), *Nephroma arcticum* (10%), *Cladonia rangiferina* (10%) and *Cladonia* spp.

This type is at an average altitude of 562 m with a 4% slope and a south/southwest exposure. The range in elevation is 453 to 671 m. The range in slope is 3 to 22%.

C7, C11 *Picea glauca, Betula nana, Salix planifolia, Carex* spp.

This community is an open *Picea glauca* community. The shrub layer is dominated by *Betula nana* (40% cover) and *Salix planifolia* (60% cover). The herbaceous layer is dominated by *Carex* spp. The data for this type was marginal and scanty which influenced the analysis. This type is an example of an outlier due to minimal information.

This community is at an average altitude of 829 m with a range in elevation from 820 to 838 m.

C8 *Picea glauca, Alnus crispa, Salix glauca, Equisetum arvense, Rubus arcticus,* feathermoss

This community has a *Picea glauca* cover in the overstory of 30% with a mean age of 139.7 years. The seedlings of this type are solely *Picea glauca. Picea mariana* is an occasional associate. The shrub cover is 5% *Alnus crispa. Picea* is approximately 15 m in height, and the *Alnus* was 3 to 5 m in height. *Salix glauca, Salix arbusculoides, Rosa acicularis* and *Viburnum edule* also contributed to the shrub cover. The herbaceous cover is made up of *Equisetum avense* (35%), *Rubus arcticus* (25%), *Arctagrostis* *latifolia* var. *arundinacea* (10%), *Calamagrostis lapponica* (10%), *Cornus canadensis* and *Equisetum sciropoides*.

The feathermosses, *Hylocomium splendens*, *Aulacomnium palustre*, *Pleurozium schreberi* and *Rhytidium rugosum* dominate the nonvascular layer with a cumulative cover value of 80%. *Peltigera* spp. and *Cladonia* spp. also contribute to the nonvascular cover.

This type is more variable in species composition with greater canopy closure than C6. The average altitude is 567 m, and the mean slope is 6% with exposures predominately south/southwest. The range in elevation is 198 to 1,021 m, and the range in slope is 0 to 30%. The substrate of this type is 65% alluvial/colluvial, 30% older moraines.

C9 *Picea glauca, Salix planifolia, Vaccinium uliginosum, Empetrum nigrum, Hylocomium splendens*

The community has an overstory of *Picea glauca* which has a mean cover value of 30%. The shrub layer is composed of *Salix* spp. (usually *Salix planifolia* ssp. *pulchra*), *Vaccinium uliginosum, Betula nana* and *Ledum palustre* with cover values of 30, 30, 20 and 10%, respectively. *Rosa acicularis, Spiraea beauverdiana* are occasionally associates.

The herbaceous cover is made up of *Empetrum nigrum* (75%), *Polygonum bistorta* (30%), *Equisetum arvense* (25%), *Cornus canadensis* (20%), *Festuca altaica* (25%), *Trisetum spicatum* (10%), *Poa arctica* (10%), *Anemone parviflora* (5%), *Petasites frigida* (5%), *Vaccinium vitis-idaea* (10%), *Carex bigelowii* (5%) and *Salix reticulata*.

The nonvascular layer is composed of *Hylocomium splendens* (75% cover), *Stereocaulon* spp. (5% cover), *Nephroma arcticum* (5% cover), *Peltigera aphthosa* (5% cover), *Cladonia* spp. (5% cover) and *Polytrichium* spp.

The mean age of this type is 124.9 years. This type is found at a mean altitude of 804 m with an average slope of 8% with a south exposure. The range in elevation is 328 to 1,000 m.

C10 *Picea glauca, Alnus crispa, Salix* spp. *Vaccinium vitis-idaea, Hylocomium splendens, Stereocaulon* spp.

This open *Picea glauca* type is found at an average altitude of 564 m with an average slope of 11% and a north exposure. The range in elevation is 518 to 610 m, and the range in slope is 8 to 13%.

The overstory of *Picea glauca* has 20% cover. The shrub cover is made up of *Alnus crispa* (30% cover), *Salix* spp. (40% cover) and *Betula nana* (20% cover). *Vaccinium vitis-idaea* (35% cover), *Carex* spp. and Gramineae are important to the herbaceous cover. *Hylocomium splendens* (60%) and *Stereocaulon* spp. (30% cover) are most significant to the nonvascular layer.

C12 *Picea glauca, Salix glauca, Salix reticulata, Arctagrostis latifolia,* feathermoss, *Cladonia rangiferina, Cladonia amaurocrea*

This community type has an overstory of *Picea glauca* with a cover value of 10 to 25%. Seedlings of *Picea glauca* are evident, and the mean age of this type is 120.4 years.

The shrub cover is composed of *Salix alaxensis* (10% cover), *Salix glauca* (10% cover), *Salix planifolia* ssp. *pulchra* (10% cover), *Betula* *nana* (10% cover), *Ledum palustre* (15% cover), *Shepherdia canadensis* (5% cover) and *Vaccinium uliginosum* (10% cover).

The herbaceous cover is composed of *Salix reticulata* (25% cover), *Arctagrostis latifolia* (30% cover), *Equisetum arvense* (10% cover), *Equisetum scirpoides, Empetrum nigrum* (10% cover), *Festuca rubra* (5% cover), *Lupinus arcticus* (10% cover), *Saussurea angustifolia* (5% cover), *Arctostaphylos rubra* (5% cover), *Senecio lugens* (5% cover), *Hedysarum alpinum* (5% cover), *Dryas integrifolia* (5% cover), *Cassiope tetragona* (5% cover).

The nonvascular layer contained the feathermosses, *Hylocomium splendens, Rhytidium rugosum, Drepanocladus uncinatus* and *Aulacomnium acuminatum* with cumulative cover of 15%. *Cladonia rangiferina, Cladonia amaurocrea, Cladonia pyxidata* var. *pocillum* and *Peltigera canina* var. *rufescens* were also contributors to the nonvascular layer.

This type was found at an average altitude of 695 m with a 9% slope and a south exposure. The range in elevation is 236 to 893 m, and the range in slope is 0 to 28%. The communities were usually disturbed with drainage gullies contributing to the variability of this type. The mean age of this type was 120.4 years, but the range in stand age was 210 years.

C13 *Picea glauca, Salix planifolia, Vaccinium uliginosum, Arctostaphylos rubra, Hedysarum alpinum, Hylocomium splendens*

The overstory cover value for *Picea glauca* in this community type is 25 to 35%. The mean age is 175.3 years. The shrub layer is composed of *Salix planifolia* ssp. *pulchra* (25% cover), *Vaccinium uliginosum* (30% cover), *Potentilla fruticosa* (10% cover) and *Shepherdia canadensis* (10% cover). *Salix hastata* and *Salix barclayi* are occasional associates.

The herbaceous cover is *Arctostaphylos rubra* (30% cover), *Salix reticulata* (25% cover), *Elymus innovatus* (10% cover), *Vaccinium vitis-idaea* (10% cover), *Empetrum nigrum* (10% cover), *Pyrola grandiflora* (25% cover), *Astragalus alpinus* (25% cover), *Hedysarum alpinum* (30% cover), *Solidago multiradiata* (10% cover), *Aster sibiricus* (10% cover), *Dryas integrifolia* (5% cover) and *Tofieldia coccina* (10% cover).

The nonvascular layer is dominated by *Hylocomium splendens* with 75% cover.

This type is found at an average altitude of 712 m with an average slope of 2% and an average aspect of 230°. The substrate is alluvial and predominately river bars. This community type has a greater closure of overstory than C12.

C14 *Picea glauca, Potentilla fruticosa, Salix planifolia, Festuca altaica,* Bryales, *Stereocaulon* spp.

The overstory of *Picea glauca* of this community type has a cover value of 40%. *Picea glauca* seedlings are evident.

The shrub layer is composed of *Salix glauca, Salix barclayi* and *Salix planifolia* ssp. *pulchra,* all with an average cover of 10%. *Betula nana* (10% cover), *Potentilla fruticosa* (15% cover) and occasionally *Vaccinium uliginosum* also occur in the shrub layer.

The major species found in the herbaceous layer are *Salix reticulata* (10% cover), *Arctostaphylos rubra* (10% cover), *Festuca altaica* (25%

cover), *Agropyron violaceum* (25% cover), *Artemisia tilesii* (5% cover), *Carex scirpoidea* (5% cover), *Sausserea angustifolia* (5% cover), *Hedysarum alpinum* (5% cover), *Poa arctica* (10% cover) and *Senecio lugens* (5% cover).

The major species of the nonvascular layer are mosses of the Bryales family (30% cover), *Stereocaulon* ssp. (25% cover), *Peltigera canina* var. *rufescens* and *Cladonia* ssp.

This community type is similar to C13 although the overstory is more closed. The average altitude of this type is 776 m ranging from 732 to 820 m. The mean age is 182 years, and the type is found on alluvial deposits.

C15 *Picea glauca, Dryas integrifolia, Agropyron violaceum, Oxytropis campestris,* Bryales

This closed *Picea glauca* community has an overstory cover value of 45%. *Picea* seedlings occur, and the age of this type is 44 years.

The major species of the shrub layer are *Salix brachycarpa* ssp. *niphoclada* (10% cover), *Potentilla fruticosa* (10% cover) and *Shepherdia canadensis* (5% cover).

The major species of the herbaceous layer are *Dryas integrifolia* ssp. *integrifolia* (75% cover), *Agropyron violaceum* (30% cover), *Oxytropis campestris* ssp. *gracilis* (25% cover), *Gentiana propinqua* ssp. *propinqua* (10% cover), *Arctostaphylos rubra* (5% cover), *Poa alpina* (5% cover) and *Solidago multiradiata* (5% cover).

The nonvascular layer is composed of Bryales (10% cover), *Rhytidium rugosum* (5%), *Distichium capillaceum* (5% cover), *Peltigera horizontalis* and *Cladonia pyxidata* var. *pocillum*.

The altitude of this type is 732 m with zero range. It is found on alluvial deposits.

This type is similar to C14, but the overstory was more closed and composed of younger trees.

Deciduous and Mixed Deciduous-Coniferous Forest

Populus balsamifera

M1 *Populus balsamifera, Salix alaxensis, Salix planifolia, Shepherdia canadensis, Arctostaphylos rubra, Senecio lugens, Hylocomium splendens*

The overstory of this community type is *Populus balsamifera* and has a cover value of 25%. The shrub layer is made up of *Salix alaxensis* (10% cover), *Salix barrattiana* (5% cover), *Salix barclayi* (5% cover), *Salix brachycarpa* spp. *niphoclada* (5% cover), *Salix planifolia* ssp. *pulchra* (10% cover), *Shepherdia canadensis* (25% cover), *Betula nana* (10% cover), *Festuca altaica* (25% cover), *Arctostaphylos rubra* (20% cover), *Arctostaphylos uva-ursi* (20% cover), *Senecio lugens* (20% cover), *Parnassia palustris* (20% cover), *Pedicularis verticillata* (10% cover), *Pyrola secunda* (10% cover), *Empetrum nigrum* (10% cover), *Salix reticulata* (10% cover), *Carex scirpoidea* (10% cover), *Epilobium latifolium* (5% cover) and *Hedysarum alpinum* (5% cover).

The major species of the nonvascular layer are the feathermosses (75% cover), *Hylocomium splendens* and *Pleurozium shreberi*. The lichens *Cladonia rangiferina, Cladonia pyxidata, Cladonia chlorophaea, Peltigera aphthosa, Peltigera canina* var. *rufescens, Cetraria ericetorum* and *Stereocaulon* spp. also occur.

The average age of this type is 86 years with *Populus balsamifera* regeneration occurring. The communities are found at an altitude of 741 m on alluvial deposits.

M2 *Populus balsamifera, Salix alaxensis, Salix glauca, Shepherdia canadensis, Senecio lugens*

The overstory of this community is *Populus balsamifera* with a closure of 25%. The age of this community is 62 years and *Populus balsamifera* regeneration is evident.

The major species of the shrub layer are *Salix* spp. *Salix alaxensis* has a cover value of 30%. *Salix arbusculoides, Salix glauca* and *Salix barclayi* have a cumulative cover of 60%. *Sheperdia canadensis* (15% cover) and *Betula nana* (5% cover) are common associates.

The major species of the herbaceous layer are *Senecio lugens* (60% cover), *Solidago multiradiata* (15% cover), *Delphinium glaucum* (20% cover), *Aster sibiricus* (30% cover), *Hedysarum alpinum* (10% cover), *Pedicularis verticillata* (5% cover), *Elymus innovatus* (5% cover), *Festuca altaica* (5% cover), *Epilobium latifolium* (5% cover) and *Poa glauca* (5% cover).

The nonvascular layer has a 10% cover value with major species being *Hylocomium splendens* and *Stereocaulon* spp.

The soils of this type are sandy, and 40% of the ground surface is unvegetated. The altitude is 649 m, and the type is found on alluvial deposits. This type is a younger gravel bar successional type than M1. There is a higher percentage of unvegetated mineral soil and decaying wood in the plots of this type.

M3 *Populus balsamifera-Alnus crispa, Dryas drummondi, Shepherdia canadensis, Agropyron violaceum*

The overstory of this type is 30% *Alnus crispa* and 10% *Populus balsamifera*. The overstory height is 3 m. *Populus balsamifera* regeneration is important to the understory with a cover value of 20%.

The major species of the shrub layer are *Shepherdia canadensis* (10%) and *Salix setchelliana* (3% cover).

The herbaceous cover is composed of *Dryas drummondi* (75%), *Agropyron violaceum* (5% cover), *Oxytropis* sp. (5% cover), *Carex aurea* and *Senecio pauperculus*.

This community is found at an altitude of 232 m on alluvial/colluvial deposits. The ground surface is 30% unvegetated sand. This is a younger successional type than M2 which is also found on gravel bars. *Alnus crispa* is more important to the overstory than in M2. *Salix alaxensis* was important in the understory, and *Alnus crispa* was absent from M2. The type M3 is found at a lower altitude than M2 and is found in the Tanana lowland as opposed to M1 and M2 which are found in the northern foothills.

This type was not aged.

Populus balsamifera-Picea glauca

M4 *Populus balsamifera-Picea glauca, Salix glauca, Juniperus communis, Elymus innovatus, Arctostaphylos uva-ursi, Hylocomium splendens*

This community type has an overstory closure of 35% with *Populus balsamifera* and *Picea glauca* codominant. The mean age of the *Populus balsamifera* is 96 years. *Picea glauca* seedlings are evident.

The major species of the shrub layer are *Salix glauca* (10% cover), *Salix brachycarpa* ssp. *niphoclada* (10% cover), *Juniperus communis* (10% cover) and *Shepherdia canadensis* (3% cover).

The major species of the herbaceous layer are *Elymus innovatus* (20% cover), *Arctostaphylos uva-ursi* (10% cover), *Calamagrostis inexpansa* (10% cover), *Oxytropis campestris* ssp. *gracilis* (5% cover) and *Hedysarum alpinum* (5% cover). *Geocaulon lividum, Carex cocinna* and *Pyrola secunda* are of scattered occurrence.

The major nonvascular species are *Hylocomium splendens* (33% cover), *Cladonia* spp. (10% cover), *Peltigera aphthosa, Cetraria cucullata* and *Polytrichium* spp.

This type was found at an average altitude of 275 m on alluvial/ colluvial deposits in the Tanana lowland.

M5 *Populus balsamifera, Picea glauca, Alnus crispa Salix alaxensis, Calamagrostis inexpansa, Tommenhypnum nitens*

This community type is predominately deciduous, although *Picea glauca* occurs occasionally in the overstory (5% cover). *Picea glauca* seedlings occur. *Populus balsamifera* has a cover value of 25%. *Alnus crispa* and *Salix alaxensis* both have cover values of 40%.

The major species of the lower shrub layer are *Salix arbusculoides* (15% cover), *Salix barclayi* (15% cover) and *Salix planifolia* ssp. *pulchra* (10% cover). *Salix scouleriana* and *Potentilla fruticosa* are occasional associates.

The herbaceous layer contains *Arctostaphylos rubra* (15% cover), *Cornus canadensis* (10% cover), *Rubus arcticus* (15% cover), *Calamagrostis inexpansa* (15% cover), *Anemone richardsonii* (5% cover) and *Parnassia kotzebuei*.

The major species of the nonvascular layer is *Tomenthypnum nitens* with 25% cover.

This community is found at a mean altitude of 281 m on alluvial/ colluvial deposits (60% of plots) or eolian deposits (40% of plots). The range in elevation is 213 to 323 m. This is also a successional flood plain type of older age than M1, M2, M3 and M4. It is exposed to occasional flooding which accounts for the relative poor development of the herbaceous and nonvascular layer. This type is found in the Tanana lowland.

M6 *Populus balsamifera, Larix laricina, Picea glauca, Salix alaxensis, Hedysarum alpinum, Epilobium angustifolium*

The overstory of this community is dominated by *Populus balsamifera* with a cover value of 35%. *Larix laricina* and *Picea glauca* occur in the subdominant strata both with cover values of 5%. *Populus balsamifera* is the oldest species with an average age of 80 years. The average age of *Larix laricina* is 50 years while *Picea glauca* is 38 years. Both *Picea glauca* and *Populus balsamifera* regeneration is evident. *Alnus crispa* (10% cover) and *Salix alaxensis* (10% cover) are important to the shrub overstory.

Major species of the shorter shrub layer are *Sheperdia canadensis* (5% cover), *Rosa acicularis* (3% cover), *Vaccinium uliginosum* (3% cover) and *Potentilla fruticosa* (2% cover).

Major species of the herbaceous layer are *Epilobium angustifolium*, *Hedysarum alpinum*, *Aster sibiricus* and *Arctostaphylos rubra*, all of 5% cover. The major species of the nonvascular layer is *Hylocomium splendens* with 5% cover.

This type is found at an average altitude of 457 m on alluvial/colluvial deposits (80% of plots) and glacial/fluvial deposits (20% of plots). The range in elevation was 227 to 640 m. The soil was sandy, and this is a flood plain successional type.

M7 *Picea glauca, Populus balsamifera, Vaccinium uliginosum, Ledum palustre, Empetrum nigrum, Pyrola grandiflora, Hylocomium splendens*

The average overstory of this type is 15% and is dominated by *Picea glauca*. *Populus balsamifera* and *Larix laricina* are associates in the subdominant layer with 10% cover and 3% cover respectively. The average age of *Picea glauca* is 125 years. The average age of *Populus balsamifera* and *Larix laricina* was 135 years and 50 years respectively. The regeneration is predominately *Picea glauca*, but young trees of *Populus balsamifera* and *Larix laricina* of 1 to 2 m in height occur.

Alnus crispa (5% cover), *Salix arbusculoides* (5% cover), *Salix barclayi* (5% cover), *Ledum palustre* (45% cover), *Vaccinium uliginosum* (45% cover), *Shepherdia canadensis* (5% cover) and *Potentilla fruticosa* (5% cover) are the major species of the shrub layer. *Rosa acicularis* and *Viburnum edule* are occasional associates.

The major species of the herbaceous layer are *Empetrum nigrum* (20% cover), *Pyrola grandiflora* (20% cover), *Cornus canadensis* (5% cover), *Arctagrostis latifolia* (3% cover), *Arctostaphylos rubra* (5% cover) and *Vaccinium vitis-idaea* (5% cover). *Mertensia paniculata, Saussurea angustifolia* and *Rubus arcticus* are occasional associates.

The major species of the nonvascular layer are *Hylocomium splendens* (60% cover) and *Polytrichium strictum* (3% cover).

This type is found at an average altitude of 410 m with an average slope of 5% with a south exposure. The range in elevation is 213 to 930 m, and the range in slope is 0 to 32%. It is found predominately on alluvial/colluvial deposits in the Tanana lowland. It is a flood plain successional type of older age than M6.

M8 *Populus balsamifera, Picea glauca, Salix alaxensis, Alnus crispa, Salix planifolia, Empetrum nigrum, Epilobium angustifolium, Hylocomium splendens*

The overstory of this type has a closure of 45% which is predominately *Populus balsamifera*. *Picea glauca* occurs in the understory. The seedlings are predominately *Picea glauca*. The average age of this type is 99 years with the *Populus balsamifera* being the oldest trees.

Salix alaxensis (30% cover) and *Alnus crispa* (30% cover) are important to the understory. The shrub layer also contains *Salix planifolia* ssp. *pulchra* (30% cover), *Salix barclayi* (20% cover), *Salix glauca* (20% cover) and *Potentilla fruticosa* (25% cover). *Rosa acicularis, Juniperus communis, Shepherdia canadensis* and *Vaccinium uliginosum* are occasional associates.

The major species of the herbaceous layer are *Empetrum nigrum* (50% cover), *Aster sibiricus* (35% cover), *Dryas integrifolia* (35% cover), *Epilobium angustifolium* (35% cover), *Rubus arcticus* (25% cover), *Arctostaphylos rubra* (25% cover), *Carex* sp. (*C. podocarpa* or *C. scirpoidea*, 20% cover), *Hedysarum alpinum* (20% cover), *Salix arctica* (20% cover), *Equisetum* sp. (20% cover), *Parnassia palustris* (10% cover) and *Festuca rubra* (8% cover). Occasional associates are *Hierocloë odorata, Calamagrostis inexpansa, Linnaea borealis* and *Arctagrostis latifolia*.

The major species of the nonvascular layer are *Hylocomium splendens* (60% cover), *Sphagnum* spp. (10% cover), *Ceratodon purpureus, Drepanocladus uncinatus* and *Aulacomnium palustre*.

This type is found at an average altitude of 664 m with a 12% slope at an aspect of 68°. The range in elevation is 485 to 914 m, and the range in slope is 0 to 39%. This is an older successional type than M7 being found on more stable river banks. The higher cover values and more species in the understory are evidence of this comparison to M7. This type is found in the northern foothills.

M9 *Populus balsamifera, Picea glauca, Alnus crispa, Rosa acicularis, Calamagrostis lapponica, Equisetum silvatiarum, Polytrichium* spp.

The closed overstory of this community type is 5% *Picea glauca* and 35% *Betula papyrifera* or *Populus balsamifera*. The regeneration was predominately deciduous.

The shrub cover was *Alnus crispa* (20% cover), *Salix alaxensis* (5% cover), *Salix arbusculoides* (5% cover), *Salix* spp. (10% cover), *Rosa acicularis* (10% cover), *Ribes triste* (1% cover) and *Viburnum edule* (3% cover). *Spiraea beauverdiana* and *Ledum palustre* ssp. *groenlandicum* are occasional associates.

The herbaceous species composition is *Calamagrostis lapponica* (30% cover), *Equisetum silvaticum* (20% cover), *Vaccinium vitis-idaea* (5% cover), *Cornus canadensis* (5% cover) and *Epilobium angustifolium* (10% cover).

The major species of the nonvascular layer are *Polytrichium* spp. (50% cover), *Cladonia* spp. (10% cover), *Peltigera* spp., *Aulacomnium* spp. and *Hylocomium splendens* (10% cover).

This type has an overstory of *Betula papyrifera* or *Populus balsamifera*. The understories are similar. The *Betula papyrifera* overstory subtype was disturbed by a 1968 fire which left evidence in fire-charred *Picea glauca* and *Betula papyrifera*. This overstory subtype was found at a mean altitude of 404 m with an elevation range of 198 to 610 m. The *Populus balsamifera* overstory subtype was found on a 39% slope of south exposure at an altitude of 610 m.

Betula papyrifera-Picea glauca

M10 *Betula papyrifera, Alnus crispa, Rosa acicularis, Vaccinium vitis-idaea, Hylocomium splendens*

This is a closed overstory community type dominated by *Betula papyrifera*. The average closure of the tree strata is 55%. *Betula papyrifera* has an average cover value of 40%. *Populus tremuloides* and *Picea glauca* are occasional associates in a subdominant position with cover values of 5% each. All three tree species are regenerating.

The major species of the shrub layer are *Alnus crispa* (10% cover) and *Rosa acicularis* (10% cover). *Ribes triste, Spiraea beauverdiana,* *Salix bebbiana* and *Ledum palustre* ssp. *groenlandicum* are occasional associates.

The herbaceous species list includes *Vaccinium vitis-idaea* (25% cover), *Cornus canadensis* (5% cover), *Linnaea borealis* (5% cover), *Calamagrostis inexpansa* (5% cover) and *Pyrola secunda* (2% cover).

The nonvascular layer is dominated by *Hylocomium splendens* (20% cover), *Peltigera* spp. and *Cladonia* spp.

This type is found at a mean altitude of 291 m on a 15% slope with a south exposure. The range in altitude is 198 to 622 m, and the range in slope is 0 to 33%. Plots within this type had a fire 20 years ago (Buskirk, 1976).

This type is found in the Tanana lowland.

M11 *Picea glauca, Betula papyrifera, Vaccinium uliginosum, Betula nana, Calamagrostis lapponica, Carex nesophila, Peltigera aphthosa*

The tree strata of this type has a cover value of 20 to 30%. The overstory is dominated by *Picea glauca* (cover value 10 to 20%). *Betula papyrifera* (cover value 20%) or *Populus balsamifera* (cover value 1%) are complementary associates. The average age of the type is 39 years, and the regeneration is *Picea glauca.* This community type is similar to M9. The understories are similar, but the overstories appear to be subtypes dominated by *Picea glauca.* The *Picea glauca-Populus balsamifera* subtype is found at an altitude of 930 m on a 22% slope and a southwest exposure. The *Picea glauca-Betula papyrifera* subtype is found at an altitude of 325 m and was disturbed by a 1969 fire. The *Betula papyrifera* and *Picea glauca* are generating in this subtype.

The major species of the shrub layer are *Betula nana* (10% cover), *Vaccinium uliginosum* (10% cover), *Ledum palustre* (5% cover) and *Rosa acicularis* (5% cover), *Spiraea beauverdiana, Salix glauca* and *Salix planifolia* ssp. *pulchra* are occasional associates.

The major species of the herbaceous layer are *Carex nesophila* (5% cover) and *Calamagrostis lapponica* (5% cover). The *Picea-Betula* subtype contains *Epilobium latifolium* in the herbaceous layer with 10% cover. The *Picea-Populus* subtype contains *Vaccinium vitis-idaea* (25% cover), *Empetrum nigrum* (25% cover) and *Poa arctica* (20% cover).

The major species of the nonvascular layer are *Peltigera aphthosa* (10% cover), *Cladonia* spp. (5% cover) and *Stereocaulon* spp. (5% cover). *Polytrichium* spp. (35% cover) is associated with the fire-charred subtype whereas *Hylocomium splendens* (35% cover) is important to the *Picea-Populus* slope subtype. The community has a mean altitude of 628 m with a range from 325 to 930 m. The average slope is 12% ranging from 1 to 22%. The exposure is south, and the type is found on sedimentary bedrock and alluvial/colluvial surficial deposits.

Betula papyrifera-Picea mariana-Larix laricina

M12 *Picea mariana, Betula papyrifera, Larix laricina, Ledum palustre Vaccinium uliginosum, Vaccinium vitis-idaea, Empetrum nigrum,* feathermoss

This community has a tree strata closure of 20 to 35%. The overstory is dominated by *Picea mariana* (20% average cover). *Larix laricina* and *Betula papyrifera* each have 10% cover values in the understory. All three species are regenerating. The average age of the *Picea mariana* is 93 years. The average age of the *Larix laricina* is 31 years.

Important species in the shrub stratum are *Salix arbusculoides* (5% cover), *Salix barclayi* (5% cover), *Salix glauca* (5% cover), *Ledum palustre* (25% cover), *Vaccinium uliginosum* (25% cover) and *Betula nana* (5% cover). *Spirea Beauverdiana, Potentilla fruticosa, Salix bebbiana* and *Salix planifolia* ssp. *pulchra* are occasional associates.

Major species of the herbaceous layer are *Vaccinium vitis-idaea* (25% cover), *Empetrum nigrum* (20% cover) and *Equisetum silvaticum* (5% cover). *Sausserea angustifolia* (10% cover), *Rubus chamaemorus* (10% cover), *Festuca rubra* (5% cover) and *Eriophorum vaginatum* (or *Carex bigelonii*) are important occasional associates.

The major species of the nonvascular layer are *Hylocomium splendens* (50%), *Pleurozium schreberi* (5%), *Sphagnum* spp. (10%), *Polytrichium* spp., *Cladonia rangiferina* (10%), *Cladonia* spp. and *Peltigera aphthosa* var. *leucoplebia*.

This type is found in the Tanana lowland at an average altitude of 264 m. The range in elevation is 198 to 334 m. The substrate is predominately alluvial/colluvial deposits (67% of plots). Eolian (17% of plots), glacial (8% of plots) and lacustrine (8% of plots) deposits underlie this type also.

M13 *Larix laricina, Betula papyrifera, Picea mariana, Ledum palustre, Betula nana, Rubus chamaemorus, Eriophorum vaginatum, Oxycoccus microcarpus*

This community type has standing charred *Larix laricina* and *Picea mariana*. Presently the tree stratum has a closure of 5 to 10%. *Larix* *laricina, Picea mariana* and *Betula papyrifera* are regenerating in approximately equal proportions.

The major species of the shrub layer are *Salix* spp. (5% cover), *Betula nana* (15% cover), *Ledum palustre* (25% cover), *Chamaedaphne calyculata* (10% cover), *Andromeda polifolia* (5% cover) and *Vaccinium uliginosum* (10% cover). The *Salix* spp. included *Salix bebbiana, Salix monticola,* and *Salix brachycarpa* ssp. *niphoclada.*

The major species of the herbaceous layer were *Oxycoccus microcarpus* (15% cover), *Rubus chamaemorus* (20% cover), *Vaccinium vitis-idaea* (15% cover), *Eriophorum vaginatum* ssp. *vaginatum* (20% cover), *Epilobium angustifolium* (5% cover) and *Carex rotundata* (5% cover). *Tofieldia pusilla, Calamagrostis lapponica, Spiranthes romanzoffiana, Stellaria calycantha* ssp. *interior, Cicuta mackenzieana, Luzula rufescens* and *Drosera rotundifolia* were occasional associates.

The major species of the nonvascular layer are *Polytrichium* spp. (10% cover), *Sphagnum* spp. (10% cover), *Marchantia polymorpha* (2% cover) and *Cladonia* spp. (2% cover).

This type is found in the Tanana lowland at an average altitude of 198 m on lacustrine deposits. There is zero range in elevation. All plots which compose this type were burned within the previous eight years (Buskirk, 1976).

Betula papyrifera

M14 *Betula papyrifera, Salix planifolia, Calamagrostis inexpansa, Carex aquatilis, Potentilla palustris*

This community type has a overstory of *Betula papyrifera* with a 5% cover value. There is standing water with 25% cover and senescent *Betula papyrifera* (5% cover value).

The shrub layer is composed of *Salix planifolia* ssp. *pulchra* (10% cover), *Salix bebbiana* (3% cover), *Salix barclayi* (5% cover). There is standing dead *Salix* with a cover value of 5%.

The major species of the herbaceous layer are *Calamagrostis inexpansa* (50% cover), *Carex aquatilis* ssp. *aquatilis* (10% cover), *Hippuris vulgaris* (5% cover) and *Potentilla palustris* (5% cover). *Glyceria pulchella, Beckmannia erucaeformis, Ranunculus pennsylvanicus, Ranunculus confervoides, Rubus arcticus* ssp. *acaulis, Potomageton epihydrus* var. *ramosus, Utricularia vulgaris* ssp. *macrorhiza* and *Utricularia intermedia* also occur.

This is the wettest forest community type sampled. It is found in the Tanana lowland at an altitude of 198 m on lacustrine deposits. There is zero range in elevation.

Low and Tall Shrub

Alnus crispa-Salix spp.

S1 *Alnus crispa, Salix alaxensis, Calamagrostic inexpansa, Rubus arcticus* feathermoss

This tall shrub community type is characterized by the dominance of *Salix alaxensis* in the shrub overstory of height 11 m. *Alnus crispa* is dominant in the understory. The oldest age is 54 years for *Salix alaxensis* and 42 years for *Alnus crispa*. The average cover values for *Salix* and *Alnus* were 50 and 60% respectively.

The major species of the herbaceous layer are *Calamagrostis inexpansa* (50% cover), *Arabis lyrata* ssp. *kamchatica* (6% cover), *Rubus arcticus* (35% cover), *Artemisia tilesii* ssp. *elatior* (35% cover), *Oxyria digyna* (35% cover) and *Galium boreale* (25% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (35% cover), *Polytrichium juniperum* (25% cover), *Polytrichium strictum* (10% cover), *Mnium thomsonii* (5% cover), *Peltigera polydactyla* (8% cover), *Peltigera canina* var. *rufescens* (8% cover) and *Sphagnum* spp. (1% cover).

This type is found at 460 m mean elevation on alluvial deposits. There is zero range in elevation. The ground surface is 30% unvegetated covered with humus, and the type is located in stream valleys.

S2 *Salix alaxensis, Salix glauca, Rosa acicularis, Petasites hyperboreus, Calamagrostis inexpansa*

This shrub community has an overstory of 3.2 m which is *Salix alaxensis* with an average cover value of 5%. The understory is composed of 1.5 m *Salix glauca* (60% cover), *Salix planifolia* ssp. *pulchra* (5% cover) and *Rosa acicularis* (12% cover).

The herbaceous layer is composed of *Petasites hyperboreus* (30% cover), *Mertensia paniculata* (10% cover), *Calamagrostis inexpansa* (10% cover), *Festuca altaica* (10% cover), *Artemisia tilesii* (10% cover), *Equisetum* *arvense* (10% cover), *Carex saxitalis* ssp. *laxa* (2% cover), *Carex podocarpa* (2% cover) and *Heracleum lanatum* (5% cover).

The nonvascular layer is composed of *Hylocomium splendens* with 5% cover, and *Stereocaulon* spp. with 1% cover.

The altitude of this type is 1,030 m with a 9% slope and a northeast exposure. There is zero range in elevation. It is found on volcanic sediments. The ground surface is 40% unvegetated covered with humus.

Alnus crispa-Salix spp.-*Betula nana*

S3 *Alnus crispa, Salix planifolia* ssp. *pulchra, Equisetum arvense, Arctagrostis latifolia, Carex bigelowii*

Alnus crispa, 2.5 m tall, dominate the shrub overstory with 67% cover. *Salix planifolia* ssp. *pulchra* (10% cover, height 1.2 m) dominates the shrub understory with frequent associates being *Alnus crispa* (10% cover), *Betula nana* (5% cover), *Viburnum edule* (10% cover), *Vaccinium uliginosum* (3% cover) and *Spiraea beauverdiana* (10% cover).

The herbaceous layer contains the major species *Equisetum arvense* (75% cover), *Carex bigelowii* (25% cover), *Arctagrostis latifolia* (25% cover), *Poa arctica* (25% cover) and *Polemonium acutiflorum* (15% cover). Occasional associates in the herbaceous layer are *Vaccinium vitis-idaea* (2% cover), *Rubus arcticus* (25% cover), *Equisetum silvaticum* (50% cover) and *Petasites hyperboreus* (25% cover).

The nonvascular layer contains the following major species with their associated mean cover values: *Polytrichium commune* (2% cover) and *Hylocomium splendens*. Occasional associates were *Sphagnum* spp. (5% cover), *Rhytidium rugosum* (2% cover) and *Rhacomitrium lanuginosum*.

This community type is found with an average slope percent of 9% and an aspect of 316°. The slope ranges from 0 to 17%. The average altitude is 780 m ranging from 703 to 817 m. It is a stream valley with wet rocky soil. Rock was hit at an average depth of 15 cm. The ground surface is 20% unvegetated covered with humus.

S4 *Alnus crispa, Salix planifolia, Lycopodium annontinum, Calamagrostis inexpansa, Spirea beauverdiana,* feathermoss

The overstory of this type is dominated by *Alnus crispa* (2.5 m tall, 75% cover). The shrub understory is dominated by *Salix planifolia* ssp. *pulchra* (1.2 m tall, 60% cover). Important associates in the shrub understory are *Spiraea beauverdiana* (30% cover), *Betula nana* (5% cover), *Vaccinium uliginosum* (5% cover) and *Ledum palustre* (1% cover).

The major species of the herbaceous layer are *Lycopodium annotinum* (20% cover), *Calamagrostis inexpansa* (5% cover), *Poa arctica* (5% cover), *Rubus arcticus* (5% cover), *Vaccinium vitis-idaea* (5% cover), *Empetrum nigrum* (5% cover). *Polemonium acutiflorum* (10% cover), *Petasites hyperboreus* (10% cover), *Epilobium angustifolium* (10% cover), *Artemisia arctica, Linnaea borealis* (5% cover) and *Polygonum bistorta* (3% cover). Important occasional associates are *Equisetum* spp. (10% cover), *Galium boreale* (5% cover), *Sanquisorba officinalis* (8% cover), *Cornus canadensis* (10% cover) and *Heracleum lanatum* (8% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (35% cover), *Drepanocladus uncinatus* (8% cover), *Polytrichium* spp. (5% cover), *Cetraria* spp. (5% cover) and *Cladonia* spp. (2% cover).

This community type is found at an average altitude of 838 m with an average slope percent of 16% and an average aspect of 237°. The range in elevation is 762 to 975 m, the range in slope is 0 to 39%, and the range in aspect is 86 to 296°. The ground surface has an unvegetated humus cover of 25%. This type is found on the lower half of the slope with 25% of the plots being found in stream valleys.

S5 *Betula nana, Salix barrattiana, Potentilla fruticosa, Festuca rubra, Hylocomium splendens*

This low shrub community is dominated by 1 m *Betula nana* in the shrub overstory (cover 65%). *Salix barrattiana* (20% cover), *Salix planifolia* ssp. *pulchra* (10% cover) and *Potentilla fruticosa* (10% cover) are important understory species.

The herbaceous layer contains the following major species: *Festuca rubra* (15% cover), *Dryas integrifolia* ssp. *sylvatica* (8% cover), *Empetrum nigrum* (5% cover), *Saussurea angustifolia* (5% cover), *Poa arctica* (5% cover), *Arctostaphylos rubra* (5% cover) and *Senecio lugens* (5% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (60% cover), *Stereocaulon* spp. (8% cover), *Cetraria islandica* (6% cover), *Peltigera aphthosa* var. *typica* (2% cover), *Cladonia amaurocrea* (2% cover), *Dactylina ramulosa* (1% cover) and *Polytrichium juniperum* (2% cover).

This low shrub community is a gravel bar community with an average vegetated cover value of 90%. The average altitude is 1,038 m, and the type is found on alluvial deposits. There is zero range in elevation. This type is found at a higher altitude and appears to be better drained than the previous vegetation type (S4). Five percent of the ground surface is unvegetated and covered with humus.

S6 *Alnus crispa, Salix planifolia, Betula nana, Empetrum nigrum, Vaccinium vitis-idaea, Hylocomium splendens*

Alnus crispa is dominant in the shrub overstory of this community type. The height of *Alnus crispa* varies from 1.2 to 2 m, and the cover varies from 5 to 75%. *Salix planifolia* ssp. *pulchra* and *Betula nana* both with average heights of .9 m and average cover values of 10% are codominant in the second shrub layer. Other associates in the shrub layer are *Vaccinium uliginosum* and *Ledum palustre* with average cover values of 30 and 10% respectively. *Spiraea beauverdiana* is an occasional associate.

The major species of the herbaceous layer are *Empetrum nigrum* (25% cover), *Vaccinium vitis-idaea* (25% cover), *Carex bigelowii* (10% cover) and *Arctagrostis latifolia* var. *latifolia* (8% cover). Important occasional associates are *Petasites hyperboreus* (10% cover), *Polygonum bistorta* (8% cover), *Polemonium acutiflorum* (2% cover) and *Poa arctica* (3% cover).

Major species of the nonvascular layer are *Hylocomium splendens* (25% cover), *Polytrichium* spp. (3% cover) and *Stereocaulon* spp. (2% cover).

This type is found at an average altitude of 894 m with an average slope percent of 9% and an average aspect of 222°. The range in elevation is 663 to 1,151 m; the range in slope is 1 to 24%, and the range in aspect is 126° to 336°. The bedrock geology is sedimentary (35%), schist/gneiss (30%), basalt/gabbroic (12%), volcanic (12%) and unknown (11%). The surficial geology is glacial moraine (35%), alluvial (24%) or bedrock (41%) for this type. The ground surface is 5% unvegetated covered with humus.

S7 *Salix glauca, Salix planifolia, Vaccinium uliginosum, Betula nana Carex bigelowii, Hylocomium splendens*

The shrub overstory of this community type is dominated by *Salix glauca* (average height = 2 m, average cover = 10%). The major species of the shrub understory are *Salix planifolia* ssp. *pulchra* (10% cover), *Betula nana* (10% cover) and *Vaccinium uliginosum* (10% cover). Occasional associates in the shrub layer are *Potentilla fruticosa* (3% cover), *Ledum palustre* (1% cover) and *Salix barclayi* (2% cover).

The major species of the herbaceous layer are *Arctagrostis latifolia* (10% cover), *Carex bigelowii* (25% cover), *Petasites hyperboreus* (10% cover), *Empetrum nigrum* (5% cover), *Vaccinium vitis-idaea* (5% cover), *Poa arctica* (10% cover), *Luzula parviflora* (10% cover), *Mertensia paniculata* (5% cover), *Valeriana capitata* (5% cover), *Festuca rubra* (10% cover), *Salix reticulata* (10% cover) and *Gentiana propinqua* ssp. *propinqua* (1% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (35% cover), *Peltigera aphthosa* (2% cover), *Polytrichium* spp. (1% cover), *Stereocaulon* spp. (1% cover). Occasional associates in the nonvascular layer were *Cladonia* spp., *Cetraria cuculatta*, *Cetraria richardsonii*, *Aulacomnium* spp. and *Pleurozium scheberi*.

This type is found at an average altitude of 998 m with an average slope percent of 8% and an average aspect of 208°. The range in elevation is 738 to 1,280 m; the range in slope is 0 to 43%, and the range in aspect is 26 to 266°. The bedrock geology is most frequently basalt/gabbroic (39% of plots). It also may be sedimentary (22% of plots), schist/gneiss (13% of plots), volcanic (17% of plots) or unknown (9% of plots). The surficial geology may be bedrock (45% of plots), alluvial (37% of plots) or glacial/fluvial (17% of plots). The ground surface is 5% unvegetated with a humus cover.

S8 *Salix planifolia, Vaccinium uliginosum, Salix reticulata, Carex podocarpa, Hylocomium splendens*

The dominant species of the shrub overstory in this type is *Salix planifolia* ssp. *pulchra* (65% cover, 1.5 m height).

Vaccinium uliginosum (25% cover) is the major species of the shrub understory. Occasional associates are *Potentilla fruticosa* (50% cover) and *Salix barclayi* (10% cover).

Major species of the herbaceous layer are *Salix reticulata* (25% cover), *Carex podocarpa* (35% cover), *Equisetum arvense* (10%), *Vaccinium vitis-idaea* (10% cover), *Poa arctica* (10% cover), *Sedum rosea* (5% cover) and *Polemonium acutiflorum* (5% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (15% cover) and *Pleurozium scheberi* (5% cover). Occasional associates are *Stereocaulon* spp., *Cladonia* spp., *Cetraria cucullata*, *Aulacomnium palustre* and *Drepanocladus uncinatus*.

This type is found at an average altitude of 852 m and is on the lower half of the slope. The range in elevation is 754 to 1,052 m. The bedrock geology is 60% sedimentary, 20% volcanic and 20% schist/gneiss. The surficial geology in 40% of the plots is alluvial deposits, in 40% of the plots is glacial moraines, and in 20% of the plots is bedrock. Other important characteristics of this type are the hummocks and uneven ground which caused differential moisture regimes with the plots of this type. The percentage of ground surface unvegetated varied from 0 to 40%.

S9 *Salix alaxensis, Salix planifolia, Sanguisorba officinalis, Petasites hyperboreus, Delphinifolium glaucum*

This shrub community has an overstory dominated by 2 m *Salix alaxensis* (30% cover) while the major species of the understory are *Salix planifolia* ssp. *pulchra* var. *pulchra* (cover 30%) and *Sanguisorba officinalis* (10% cover).

The major species of the herbaceous layer are *Petasites hyperboreus* (30% cover), *Delphinium glaucum* (25% cover), *Calamagrostis inexpansa* (5% cover), *Festuca* spp. (8% cover), *Mertensia paniculata* (8% cover) and *Rubus arcticus* (5% cover).

This type has a ground surface which was 25% unvegetated and covered with humus. The bedrock geology is sedimentary, and the surficial geology is alluvial/colluvial deposits. It is the lower half of a slope community found at an altitude of 591 m. There is zero range in elevation. This type is found in the Tanana-Kuskokwim lowland section (Talkeetna quadrangle).

S10 *Salix barclayi, Equisetum palustre, Carex podocarpa, Hylocomium splendens*

The major species of the shrub layer are *Salix barclayi* (height = 1.8 m, 70% cover), *Salix planifolia* ssp. *pulchra* (5% cover, 1 m height), *Salix alaxensis* (height = 3 m; 1% cover) and *Sanguisorba officinalis* (5% cover). Occasional associates are *Vaccinium uliginosum* and *Potentilla fruticosa*.

The major species of the herbaceous layer are *Rubus arcticus* (6% cover), *Carex podocarpa* (25% cover), *Achillea borealis* (10% cover), *Equisetum palustre* (25% cover), *Epilobium angustifolium* (5% cover) and *Arctagrostis latifolia* (10% cover). Occasional important associates are *Sedum rosea* (1% cover), *Petasites hyperboreus* (5% cover), *Anemone* sp. (5% cover), *Polygonum bistorta* (5% cover), *Artemisia arctica* (5% cover) and *Angelica lucida* (5% cover).

The nonvascular layer was composed of *Hylocomium splendens* (10% cover), *Polytrichium strictum* (2% cover), *Aulacomnium palustre* (5% cover). Occasional associates were *Sphagnum* spp., *Tomenhypnum nitens* and *Cladonia* spp.

This type is found at an average altitude of 868 m with a 2% slope and an average aspect of 276°. The range in elevation is 735 to 936 m;

the range in slope is 0 to 7%, and there is zero range in aspect. It is found in the Cook Inlet-Susitna lowland physiographic region. The type is found on alluvial deposits and in stream valleys. The ground surface is 10% unvegetated with a humus cover.

Salix spp.-*Shepherdia canadensis*

S11 *Salix alaxensis, Salix barclayi, Shepherdia canadensis, Epilobium angustifolium*

The shrub overstory is dominated by *Salix alaxensis* with a height of 2 m and an average cover of 35%. The shrub understory of this type is composed of *Salix barclayi* (1 m tall, 35% cover) and *Shepherdia canadensis* (.6 m height, 35% cover).

The major species of the herbaceous layer are *Epilobium angustifolium* (25% cover), *Salix reticulata* (5% cover), *Solidago multiradiata* (5% cover), *Angelica lucida* (5% cover), *Rubus arcticus* (5% cover), *Empetrum nigrum* (2% cover) and *Heracleum lanatum* (1% cover). Occasional associates were *Cornus canadensis* (5% cover), *Mertensia paniculata* (2% cover), *Dryas octopetala* (2% cover), *Saxifraga tricuspidata* (2% cover), *Aster sibiricus* (5% cover) and *Stellaria monatha* (2% cover).

The major species of the nonvascular layer are *Pleurozium scheberi* (5% cover) and *Peltigera aphthosa* var. *leucoplebia* (2% cover). *Polytrichium* spp., *Cetraria islandica* and *Lobaria linita* were occasionally found in this type also.

The average altitude was 803 m, and it is a stream valley type found on alluvial deposits. The range in elevation is 701 to 866 m. The ground surface was 10% unvegetated covered with humus.

S12 *Salix alaxensis, Salix planifolia, Shepherdia canadensis, Festuca altaica, Hylocomium splendens*

The shrub overstory of this community type is dominated by *Salix alaxensis* (4 m in height, 10% cover). The shrub understory is also dominated by *Salix* spp. averaging 1.2 m in height with an average cover value of 35%. The *Salix* spp. are most frequently *Salix planifolia* ssp. *pulchra, Salix glauca* and *Salix barclayi*. Other species of the shrub layer are *Shepherdia canadensis* (5% cover) and occasionally *Vaccinium uliginosum* (1% cover).

The herbaceous cover is composed of *Festuca altaica* (20% cover), *Mertensia paniculata* (6% cover), *Parnassia kotzebui* (5% cover), *Anemone parviflora* (5% cover), *Artemisia tilesii* (5% cover) and *Dryas octopetala* (5% cover). Important occasional associates in the herbaceous layer are *Arctostaphylos rubra* (10% cover), *Aconitum delphinifolium* (5% cover), *Senecio lugens* (5% cover), *Carex* sp. (5% cover), *Aster sibiricus* (2% cover), *Salix arctica* (2% cover), *Cnidium cnidifolium* (1% cover) and *Vaccinium vitis-idaea* (2% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (25% cover), *Pleurozium scheberi* (5% cover), *Peltigera aphthosa* (2% cover) and *Polytrichium* sp. (1% cover). Occasional associates are *Peltigera venosa, Lobaria linita, Thamnolia vermicularis, Stereocaulon* sp.*, Dactylina ramulosa, Drepanocladus uncinatus* and *Dicranum* sp.

This type is found at an average altitude of 970 m, with an average slope percent of 9% and an average aspect of 117°. The range in elevation is 728 to 1,059 m; the range in slope is 0 to 17%, and the range in aspect is 26 to 176°. The bedrock geology in 82% of the plots is sedimentary/metasedimentary, in 9% of the plots is schist/gneiss and in 9% of the plots is unknown. The surficial geology in 55% of the plots is bedrock, in 27% of the plots is alluvial, in 9% of the plots is glacial/fluvial and in 9% of the plots is lacustrine deposits. The ground surface is 10% unvegetated and covered with humus or mineral soil.

Salix spp.

S13 *Salix alaxensis, Betula nana, Festuca altaica, Salix reticulata, Dryas integrifolia*

This shrub community has an overstory dominated by *Salix alaxensis* (height of 2 m, cover 15%). The major species of the shrub understory are *Salix glauca* (height 1.5 m, cover 10%) and *Betula nana* (height 1 m, cover 10%). Frequent associates with the shrub layer are *Shepherdia canadensis* (3% cover) and other *Salix* spp.

Major species of the nonvascular layer are *Festuca altaica* (10% cover), *Salix reticulata* (10% cover), *Parnassia kotzebui* (6% cover), *Hedysarum alpinum* (8% cover), *Dryas integrifolia* (10% cover), *Arctostaphylos rubra* (10% cover), *Pedicularis capitata* (10% cover) and *Solidago multiradiata* (10% cover).

The nonvascular layer is composed of *Hylocomium splendens* (3% cover), *Polytrichium* spp. (2% cover) and *Stereocaulon* spp. (2% cover). Occasional associates in the nonvascular layer are *Thamnolia vermicularis, Pleurozium scheberi, Rhytidium rugosum, Cetraria cucullata, Cetraria richardsonii, Cetraria islandica* and *Distichium* spp.

This type is found at an average altitude of 951 m with an average slope percent of 5% and an average aspect of 275°. The range in elevation is 762 to 1,082 m; the range in slope is 0 to 22%, and the range in aspect is 146 to 356°. The bedrock geology is 67% sedimentary/metasedimentary, 22% basalt/gabbroic and 11% volcanic. The surficial geology is 100% alluvial deposits.

This is a gravel bar community, and the ground surface is 5 to 10% unvegetated.

S14 *Salix barrattiana, Betula nana, Dryas integrifolia, Gentiana propinqua, Pleurozium scheberi*

The shrub layer is dominated by *Salix barrattiana* (.8 m height, 50% cover). *Betula nana* (25% cover) and occasionally *Shepherdia canadensis* and *Salix brachycarpa* ssp. *niphoclada* (10% cover) also contribute to the shrub layer.

The major species of the herbaceous layer are *Festuca altaica* (10% cover), *Gentiana propinqua* (10% cover), *Aconitum delphinifolium* (5% cover), *Dryas integrifolia* (25% cover), *Arctostaphylos uva-ursi* (6% cover), *Elymus innovatus* (5% cover), *Astragalus nutzotinensis* (5% cover), *Carex scirpoidea* (10% cover), *Pedicularis verticillata* (8% cover), *Pyrola grandiflora* (5% cover) and *Zygadenus elegans* (10% cover).

The major species of the nonvascular layer are *Pleurozium scheberi* (25% cover), *Dicranum* spp. (5% cover), *Stereocaulon* spp. (2% cover), *Peltigera canina* var. *rufescens*, *Peltigera aphthosa* var. *leucoplebia*, *Cladonia chlorophaea*, *Cladonia pyxidata*, *Cladonia cyanipes/bacilliformis*, *Cladonia coccifera, Cetraria cucullata, Cetraria islandica, Ceratodon purpureus* and *Drepanocladus uncinatus*.

The average altitude is 735 m, and this type is found on alluvial deposits. The range in elevation is 725 to 754 m. It is a valley association with very sandy soils. The depth of sandy penetrable soil was 6 cm average. The ground surface is 20% unvegetated covered with 10% humus and 10% mineral soil.

S15 *Salix alaxensis, Shepherdia canadensis, Dryas octopetala, Arctostaphylos rubra*

The shrub overstory of this type is composed of *Salix alaxensis* with a height of 2.5 m and 20% cover. The other major species of the shrub layer are *Shepherdia canadensis* (5% cover), *Salix glauca* (5% cover) and *Potentilla fruticosa* (2% cover). Species occasionally found in this type are *Salix arbusculoides* (5% cover), *Salix barrattiana* (2% cover) and *Betula nana* (10% cover).

The major species of the herbaceous layer are *Dryas octopetala* (30% cover), *Aster sibiricus* (10% cover), *Anemone parviflora* (10% cover), *Arctostaphylos rubra* (30% cover), *Salix reticulata* (10% cover), *Festuca altaica* (10% cover), *Hedysarum alpinum* (5% cover), *Anemone parviflora* (5% cover) and *Epilobium latifolium* (5% cover). Species that occur occasionally in this type were *Oxytropis borealis, Draba alpina* and *Carex sciropoidea*.

The major species of the nonvascular layer are *Hylocomium splendens* (5% cover), *Pleurozium scheberi* (1% cover), *Stereocaulon* spp. (1% cover) and *Peltigera scabrosa*.

This is a gravel bar community, and the ground surface is 25% unvegetated. The type is found at an average altitude of 1,060 m on alluvial deposits. The range in elevation is 1,038 to 1,082 m. The average slope percent is 7%, and the range is 0 to 13%. The aspect is 296°.

S16 *Salix alaxensis, Alnus crispa, Salix arbusculoides, Artemisia tilesii*

The dominant species in the shrub overstory of this type is *Salix alaxensis* which is 4 m tall with a cover value of 35%. *Alnus crispa* (2 m tall, 40% cover), *Salix arbusculoides* (1.5 m tall, 10% cover) and *Viburnum edule* (5% cover) are the other major shrub species.

The major species of the herbaceous layer are *Artemisia tilesii* (30% cover), *Epilobium latifolium* (8% cover), *Epilobium angustifolium* (8% cover), *Calamagrostis lapponica* (5% cover), *Parnassia kotzebui* (3% cover), *Salix reticulata* (2% cover), *Aconitum delphinifolium* (3% cover), *Solidago multiradiata* (3% cover), *Erigeron acris* ssp. *politus* (1% cover), *Dryas octopetala* (5% cover), *Oxytropis maydelliana* (3% cover), *Pedicularis capitata* (3% cover) and *Poa arctica* (3% cover).

The major species of the nonvascular layer is *Hylocomium splendens* (4% cover).

This type is found at an altitude of 579 m with a 50% slope. There is zero range in elevation. It is a creek bank community found on alluvial deposits. The ground surface is 30% unvegetated, covered with humus, mineral soil and rock. The aspect is 156°.

Dwarf Shrub and Shrub Tundra

Salix spp.-*Shepherdia canadensis*

T1 *Salix glauca, Shepherdia canadensis, Dryas integrifolia, Artemisia frigida, Festuca rubra*

The major species of the shrub layer are *Salix alaxensis* (1.5 m tall, 5% cover), *Salix glauca* (1 m tall, 15% cover), *Salix barclayi* (.8 m tall, 15% cover) and *Shepherdia canadensis* (.6 m tall, 10% cover).

The major species of the herbaceous layer are *Dryas integrifolia* (25% cover), *Artemisia frigida* (20% cover), *Solidago multiradiata* (10% cover), *Festuca rubra* (10% cover) and *Poa glauca* (3% cover). Species that occur occasionally in this type are *Potentilla fruticosa, Agropyron violaceum, Minuartia macrocarpa, Pyrola secunda* and *Parnassia kotzebui*.

The nonvascular layer is composed of *Rhacomitrium canescens* (5% cover), *Polytrichium juniperinum* (5% cover), *Cladonia pyxidata* (2% cover), *Peltigera aphthosa* (2% cover), *Cetraria cucullata* (2% cover), *Cladonia* spp. (2% cover).

This type is found at an altitude of 953 m with a 17% slope and an average aspect of 226°. The elevation ranges from 945 to 960 m; the slope ranges from 6 to 28%, and the aspect ranges from 116 to 336°. It is found on older glacial moraines. The ground surface is 45% unvegetated. Of the unvegetated surface, 35% is rocky glacial debris and 10% is humus.

T2 *Salix glauca, Shepherdia canadensis, Vaccinium uliginosum, Dryas integrifolia, Saxifraga tricuspidata, Polytrichium commune*

The major species of the shrub layer are *Salix glauca* (10% cover, 1 m height), *Salix monticola* (5% cover, 1 m height), *Shepherdia canadensis* (5% cover, 1 m height) and *Vaccinium uliginosum* (5% cover, .8 m height).

The major species of the herbaceous layer are *Dryas integrifolia* (10% cover), *Saxifraga tricuspidata* (10% cover), *Festuca altaica* (5% cover), *Salix reticulata* (5% cover), *Astragalus alpinus* ssp. *alpinus* (5% cover), *Artemisia tilesii* (5% cover), *Solidago multiradiata* (5% cover), *Poa arctica* ssp. *arctica* (2% cover), *Stellaria monatha* (1% cover) and *Epilobium angustifolium* (2% cover).

The major species of the nonvascular layer are *Polytrichium commune* (10% cover), *Rhytidium rugosum* (8% cover), *Rhacomitrium canescens* (6% cover), *Cetraria islandica* (3% cover), *Cetraria cucullata* (3% cover), *Dactylina ramulosa* (1% cover), *Cladonia* spp. (2% cover) and *Pertusaria* spp. (1% cover).

This type is also found on older glacial moraines at an altitude of 884 m. There is zero range in elevation. The average slope percent is 22% with an aspect of 156°. The ground surface is 35% unvegetated of which 25% is covered with rocky glacial moraines and 10% covered with dark soil and humus.

Salix spp.

T3 *Salix glauca, Salix reticulata, Festuca altaica, Dryas octopetala*

The major species of the shrub layer of this type is *Salix glauca* (1 m height, 10% cover). Species that occur occasionally in this type are *Salix barrattiana* and *Potentilla fruticosa.*

The major species of the herbaceous layer are *Salix reticulata* (25% cover), *Dryas octopetala* (30% cover), *Festuca altaica* (25% cover), *Artemisia arctica* (10% cover), *Hedysarum alpinum* (5% cover), *Anemone parviflora* (8% cover) and *Gentiana propinqua* (3% cover). Important occasional associates in the herbaceous layer are *Salix arctica* (10% cover), *Festuca rubra* (10% cover), *Senecio lugens* (5% cover), *Solidago multiradiata* (5% cover), *Epilobium latifolium* (5% cover), *Polygonum bistorta* (5% cover), *Equisetum sciropoides, Poa arctica* (5% cover), *Carex* spp. (5% cover), *Aster sibiricus* (2% cover) and *Silene acaulis.*

The major species of the nonvascular layer are *Hylocomium splendens* (10% cover), *Peltigera canina* var. *rufescens* (2% cover), *Stereocaulon* spp. (2% cover), *Rhytidium rugosum, Tortula mucronifilia, Rhacomitrium canescens* and *Cetraria cucullata.*

This type occurs at an average altitude of 1,163 m with 14% slope and an aspect of 158°. The range in elevation is 920 to 1,305 m; the range in slope is 0 to 37%, and the range in aspect is 026 to 356°. The bedrock geology is 62% sedimentary/metasedimentary, 23% basalt/gabbroic, 8% schist/gneiss and 8% volcanic. The surficial geology is 38% alluvial/colluvial deposits, 31% glacial moraines and 31% bedrock. The ground surface is 5% weathered rock.

T4 *Salix brachycarpa, Dryas octopetala, Salix reticulata, Cassiope tetragona,* feathermoss

The shrub layer if it exists in this type is occasionally composed of the following species: *Salix glauca* (1 m height, 1% cover), *Salix brachycarpa* ssp. *niphoclada* (.3 m height, 30% cover) and *Salix barrattiana* (.2 m height, 5% cover).

The major species of the herbaceous layer are *Salix arctica* (10% cover), *Salix reticulata* (25% cover), *Anemone parviflora* (5% cover), *Festuca rubra* (10% cover), *Dryas octopetala* (30% cover), *Silene acaulis* (3% cover), *Poa alpina* (6% cover), *Epilobium latifolium* (4% cover), *Trisetum spicatum* (6% cover) and *Saxifraga hieracifolia.* Occasional associates in the herbaceous layer are *Cassiope tetragona* (10% cover), *Androsace chamaejasme* ssp. *lehmanniana* (5% cover), *Aster alpinus* (3% cover) and *Cnidium cnidiifolium* (5% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (5% cover), *Rhacomitrium canescens* (5% cover), *Aulacomnium palustre* (5% cover), *Distichium capillaceum* (3% cover), *Polytrichium* spp. (2% cover), *Peltigera aphthosa* var. *leucoplebia* (2% cover), *Cetraria islandica* (1% cover), *Stereocaulon* spp. (2% cover), *Thamnolia vermicularis* (2% cover) and *Dactylina ramulosa.* Other nonvascular species which occur frequently in this type are *Pertusaria* spp., *Peltigera canina* var. *rufescens, Lobaria linita, Cladonia chlorophaea, Rhytidium rugosum* and *Cetraria cucullata.*

This community type is found at an average altitude of 1,265 m with a 28% slope and an average aspect of 205°. The range in elevation is

1,052 to 1,654 m; the range in slope is 2 to 50%, and the range in aspect is 056 to 326°. The bedrock geology in 88% of the plots is sedimentary/metasedimentary, in 6% of the plots is volcanic and in 6% of the plots is granitic. The surficial geology in 76% of the plots is bedrock, in 12% of the plots is glacial moraines and in 12% of the plots is alluvial deposits. The ground surface of this type is 35% unvegetated weathered rock and mineral soil.

Dryas octopetala

T5 *Dryas octopetala, Vaccinium uliginosum, Salix arctica, Carex microchaeta, Hierochloe alpina, Hylocomium splendens*

The major species of this community type are *Dryas octopetala* (35% cover), *Vaccinium uliginosum* (.1 m height, 10% cover), *Salix arctica* (10% cover), *Hierochloe alpina* (8% cover), *Anemone parviflora* (8% cover), *Senecio lugens* (8% cover), *Oxytropis nigrescens* (8% cover), *Carex microchaeta* (10% cover), *Diapensia lapponica* (2% cover) and *Ligusticum mutellinoides* ssp. *alpinum* (5% cover). Other species which occur frequently in this type are *Poa arctica* (3% cover), *Campanula lasiocarpa* (5% cover), *Carex scirpoidea* (5% cover), *Luzula confusa* (5% cover), *Arenaria chamissonis* (2% cover), *Polygonum bistorta* (2% cover), *Pedicularis capitata* (3% cover), *Cassiope tetragona* (2% cover), *Gentiana algida* (2% cover), *Primula tschuktschorum* ssp. *tschuktschorum* (2% cover), *Castilleja elegans* (2% cover), *Geum rosii* (1% cover), *Antennaria friesiana* ssp. *friesiana* and *Saxifraga eschscholtzii*.

The major species of the nonvascular layer are *Hylocomium splendens* (10% cover), *Stereocaulon* spp. (2% cover), *Rhacomitrium canescens* (5% cover), *Polytrichium juniperum* (4% cover), *Rhytidium rugosum* (3% cover), *Dactylina ramulosa* (1% cover), *Cetraria nivalis* (1% cover), *Sphaerophorus globosus, Cetraria islandica, Peltigera pratexta, Thamnolia vermicularis, Asahinea chrysantha, Cetraria cucullata, Alectoria* spp., *Parmelia* spp. and *Cladonia* spp.

This type is found at an altitude of 1,200 m with a 8% slope and an aspect of 165°. The range in elevation is 1,073 to 1,311 m; the range in slope is 0 to 44%, and the range in aspect is 026 to 326°. The bedrock geology in 33% of the plots is sedimentary/metasedimentary, in 33% of the plots is basalt/gabbroic, in 17% of the plots is volcanic, in 11% of the plots is schist/gneiss and in 6% of the plots is granitic. The surficial geology in 72% of the plots is bedrock, in 22% of the plots is alluvial deposits and in 6% of the plots is older glacial moraines. The ground surface is 28% unvegetated weathered rock and mineral soil.

T6 *Dryas octopetala, Salix arctica, Carex microchaeta, Oxytropis nigrescens, Hylocomium splendens*

The major species of this herbaceous community type are *Dryas octopetala* ssp. *octopetala* (50% cover), *Salix arctica* (25% cover), *Oxytropis nigrescens* ssp. *bryophila* (5% cover), *Carex microchaeta* (10% cover), *Senecio lugens* (3% cover), *Minuartia arctica* (2% cover), *Anemone parviflora* (3% cover), *Ligusticum mutellinoides* ssp. *alpinum* (3% cover), *Castilleja elegans* (3% cover), *Poa arctica* (3% cover), *Trisetum spicatum*

(3% cover), *Silene acaulis* (1% cover), *Saxifraga reflexa* (2% cover) and *Campanula lasiocarpa* (2% cover). Other species which occur frequently in this type are *Festuca brachyphylla, Luzula tundricola, Luzula confusa, Diapensia lapponica, Senecio residifolius, Saxifraga flagellaris* ssp. *setigera, Polygonum viviparum, Pedicularis capitata, Artemisia arctica, Polygonum bistorta, Draba nivalis, Potentilla uniflora, Antennaria monocephala* ssp. *monocephala* and *Senecio residifolius*.

The major species of the nonvascular layer are *Hycolomium splendens* (5% cover), *Thamnolia vermicularis, Cetraria islandica, Cetraria cucullata, Cetraria nivalis, Peltigera aphthosa, Stereocaulon* spp.*, Lobaria linita, Rhytidium rugosum, Rhacomitrium canescens, Distichium capillaceum, Pertusaria* spp.*, Asahinea chrysantha, Alectoria nigricans, Polytrichium juniperum, Drepanocladus uncinatus, Sphaerophorus globosus* and *Cladonia* spp.

This type is found at an altitude of 1,285 m with a 16% slope and an aspect of 201°. The range in elevation is 1,068 to 1,494 m; the range in slope is 2 to 41%, and the range in aspect is 26 to 356°. The bedrock geology in 46% of the plots is basalt/gabbroic, in 30% of the plots is sedimentary/metasedimentary, in 12% of the plots is volcanic and in 12% of the plots is schist/gneiss. The surficial geology in 81% of the plots is bedrock, in 15% of the plots is older glacial moraines and in 4% of the plots is alluvial. This type when compared to T5 has no *Vaccinium uliginosum* and a higher cover of *Dryas octopetala* and *Salix arctica*. The species composition is similar, but there are species exclusive to either type as *Hierocloe alpinum* (in T5) and *Senecio* *residifolius* (in T6). T6 is found on steeper slopes with a more southwestern exposure. The ground surface is 36% unvegetated weathered rock and mineral soil in T6. This value was 28% in T5. The ground surface of T6 is terraced as a result of solifluction.

T7 *Dryas octopetala, Salix arctica, Salix reticulata, Poa arctica, Carex microchaeta, Luzula tundricola, Hylocomium splendens*

The major species of this herbaceous community type are *Dryas octopetala* ssp. *octopetala* (35% cover), *Salix arctica* (10% cover), *Salix reticulata* (10% cover), *Poa arctica* (10% cover), *Carex microchaeta* (10% cover), *Oxytropis nigrescens* ssp. *bryophila* (5% cover), *Ligusticum mutellinoides* ssp. *alpinum* (4% cover), *Cassiope tetragona* (5% cover), *Hierochloe alpina* (10% cover), *Luzula tundricola* (10% cover), *Saxifraga punctata* (5% cover), *Polygonum bistorta* (5% cover) and *Polygonum viviparum* (2% cover). Important species that occur frequently in this type are *Synthyris borealis* (5% cover), *Petasites hyperboreus* (3% cover), *Saxifraga hieracifolia* (1% cover), *Sausseria viscida* var. *yukonensis* (3% cover), *Anemone parviflora* (4% cover), *Trisetum spicatum* (5% cover), *Polemonium acutiflorum* (3% cover), *Pedicularis* sp. (3% cover), *Senecio residifolius* (3% cover) and *Diapensia lapponica* (1% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (25% cover), *Cetraria cucullata* (2% cover), *Stereocaulon* spp. (1% cover), *Polytrichium juniperum* (2% cover), *Rhacomitrium canescens* (2% cover), *Rhytidium rugosum* (2% cover), *Thamnolia vermicularis, Asahinea chrysantha, Lobaria linita, Cetraria islandica, Cetraria richardsonii, Peltigera* *aphthosa, Cladonia* spp., *Cladonia rangiferina, Ceratodon purpureus, Aulacomnium turgidium* and *Mnium thomsonii.*

This type occurs at an average altitude of 1,267 m with a slope of 12% and an average aspect of 205°. The range in elevation is 945 to 1,379 m; the range in slope is 3 to 33%, and the range in aspect is 16 to 356°. The bedrock geology in 42% of the plots is sedimentary/metasedimentary, in 29% of the plots is basalt/gabbroic and in 29% of the plots is schist/gneiss. The surficial geology in 86% of the plots is bedrock, in 9% of the plots is glacial moraines and in 5% of the plots is alluvial deposits. The ground surface in this type is 12% unvegetated weathered rock and mineral soil. Frost boils and processes are evident as circular unvegetated areas except for the crustose rock lichens. The soil was penetrable to a .04 m depth where the rockiness of the profile prevented further penetration.

T7 appeared to have more available moisture than T6 due to less slope and less unvegetated ground.

T8 *Dryas octopetala, Cassiope tetragona, Vaccinium uliginosum, Salix reticulata, Salix arctica,* feathermoss, *Stereocaulon* spp..

The major shrub species of this type are *Vaccinium uliginosum* (.08 m height, 15% cover) and *Rhododendron lapponicum* (.05 m height, 5% cover). Species that occur occasionally in the shrub layer are *Salix glauca* (.4 m height, 2% cover), *Salix barrattiana* (.1 m height, 2% cover), *Salix planifolia* ssp. *pulchra* (.4 m height, 2% cover), *Potentilla fruticosa* (.1 m height, 1% cover), *Betula nana* (.1 m height, 2% cover).

The major species of the herbaceous layer are *Cassiope tetragona* (25% cover), *Salix reticulata* (10% cover), *Salix arctica* (10% cover), *Dryas octopetala* ssp. *octopetala* (25% cover), *Carex microchaeta* (5% cover), *Anemone parviflora* (5% cover), *Festuca altaica* (8% cover) and *Silene acaulis* (2% cover). Important species that occur frequently in this type are *Arctostaphylos rubra* (5% cover), *Astragalus umbellatus* (5% cover), *Pedicularis capitata* (2% cover), *Hierochloe alpina* (5% cover), *Poa arctica* (5% cover), *Diapensia lapponica* (2% cover), *Lupinus arcticus* (3% cover), *Minuartia arctica* (2% cover) and *Polygonum bistorta* (2% cover).

Major species of the nonvascular layer are *Hylocomium splendens* (10% cover), *Cetraria cucullata* (3% cover), *Stereocaulon* spp. (5% cover), *Thamnolia vermicularis* (2% cover), *Aulacomnium turgidum, Polytrichium juniperum, Distichium capillaceum, Rhytidium rugosum, Aulacomnium palustre, Lobaria linita, Cetraria islandica, Dactylina ramulosa, Peltigera aphthosa* var. *leucoplebia, Cornicularia divergens, Cetraria nivalis, Sphaerophorus globusus* and *Cladonia* spp.

This type is found at an average altitude of 1,135 m on a 15% slope with an average aspect of 183°. The range in elevation is 823 to 1,341 m; the range in slope is 1 to 33%, and the range in aspect is 026 to 306°. The bedrock geology in 50% of the plots is sedimentary/metasedimentary, in 20% of the plots is basalt/gabbroic, in 10% of the plots is volcanic, in 10% of the plots is schist/gneiss and in 10% of the plots is unknown. The surficial geology in 90% of the plots is bedrock and in 10% of the plots is older glacial moraines.

The ground surface is 12% unvegetated. This type is found at a lower altitude than T4-T7. It is a moister type than T5, T6, T7.

T9 *Carex canescens, Carex rhynchophysa, Agropyron violaceum, Rorippa islandica, Sphagnum* spp.

This type is a seasonal *Carex* meadow with a seasonal receding water level. The major species are *Carex canescens* (20% cover), *Carex rhynchophysa* (20% cover), *Agropyron violaceum* (10% cover), *Rorippa islandiea* (10% cover), *Ranunculus gmelini* (10% cover), *Hippuris vulgaris* (5% cover), *Equisetum fluviatile* (5% cover) and *Sphagnum* spp. (50% cover).

This type is found at an average altitude of 572 m. The bedrock is sedimentary and the surficial geology is glacial/fluvial.

Betula nana-Ericaceons-Salix spp.

T10 *Vaccinium uliginosum, Betula nana, Salix arctica, Salix reticulata, Ledum decumbens, Dryas octopetala,* feathermoss

The major species of the shrub layer are *Betula nana* (.5 m height, 25% cover), *Vaccinium uliginosum* (.3 m height, 10% cover) and *Ledum decumbens* (.2 m height, 10% cover). Species occasionally occurring with the shrub layer of this type are *Salix planifolia* ssp. *pulchra* (.8 m height, 10% cover) and *Salix glauca* (.8 m height, 10% cover).

The major species of the herbaceous layer are *Empetrum nigrum* (10% cover), *Vaccinium vitis-idaea* (10% cover), *Salix arctica* (10% cover), *Salix reticulata* (10% cover), *Carex microchaeta* (5% cover), *Festuca altaica* (10% cover), *Dryas octopetala* ssp. *octopetala* (20% cover), *Artemisia arctica* (10% cover) and *Arctostaphylos arctica* (5% cover).

Important species that occur frequently in this type are *Diapensia lapponica* (5% cover), *Poa arctica* (5% cover), *Tofieldia coccinea* (3% cover), *Arctagrostis latifolia* (5% cover), *Epilobium latifolium* (5% cover), *Petasites hyperboreus* (5% cover) and *Polygonum bistorta* (5% cover).

The major species of the nonvascular layer are *Hylocomium splendens* (10% cover), *Polytrichium juniperum* (4% cover), *Rhytidium rugosum* (4% cover), *Pleurozium scheberi* (4% cover), *Rhacomitrium lanuginosum* (3% cover), *Drepanocladus uncinatus, Cetraria nivalis, Cladonia arbuscula, Cladonia rangiferina, Cladonia* spp.*, Stereocaulon* spp.*, Dactylina ramulosa, Thamnolia vermicularis, Peltigera aphthosa* var. *leucoplebia, Nephroma arcticum, Cetraria islandica, Lobaria linita* and *Asahinea chrysantha.*

This type is found at an average altitude of 939 m with a 10% slope and an average aspect of 162°. The range in elevation is 579 to 1,167 m; the range in slope is 0 to 39%, and the range in aspect is 16 to 356°. The bedrock geology in 60% of the plots is sedimentary/metasedimentary, in 10% of the plots is volcanic/metavolcanic, in 10% of the plots is schist/gneiss, in 6% of the plots is basalt/gabbroic and in 5% of the plots is unknown.

The surficial geology in 35% of the plots is glacial moraines, in 44% of the plots is bedrock, in 18% of the plots is alluvial and in 2% of the plots is unknown. This type is 5% unvegetated weathered rock and mineral soil. Frost boils and patterned (pyramidal formation) ground due to solifluction are evident in this type.

Betula nana-Salix spp.

T11 *Salix planifolia, Betula nana, Calamagrostis lapponica, Petasites hyperboreus,* feathermoss

The major species of the shrub layer in this type are *Salix planifolia* ssp. *pulchra* (30% cover, 1 m height), *Betula nana* (.8 m height, 10% cover) and *Spiraea beauverdiana* (.7 m height, 10% cover).

The major species of the herbaceous layer are *Calamagrostis lapponica* (50% cover), *Polemonium acutiflorum* (5% cover), *Rubus arcticus* (10% cover), *Aconitum delphinifolium* (5% cover), *Epilobium angustifolium* (5% cover) and *Petasites hyperboreus* (20% cover). Important species that occur occasionally in this type are *Vaccinium vitis-idaea* (15% cover), *Empetrum nigrum* (15% cover), *Luzula tundricola* (5% cover), *Heracleum lanatum* (5% cover) and *Sanguisorba officinalis* (3% cover).

Major species of the nonvascular layer are *Hylocomium splendens* (30% cover), *Polytrichium* spp. (10% cover), *Rhytidium rugosum* (5% cover), *Cetraria* spp. (10% cover), *Cladonia* spp. (10% cover), *Peltigera* spp. (5% cover), *Nephroma* spp. (5% cover) and *Pleurozium scheberi* (5% cover).

This type is found at an average altitude of 844 m with an 8% slope and an average aspect of 198°. The range in elevation is 732 m; the range in slope is 1 to 33%, and the range in aspect is 166 to 296°. The bedrock geology in 89% of the plots is sedimentary/metasedimentary and in 11% of the plots is volcanic. The surficial geology in 56% of the plots is bedrock, in 33% of the plots is glacial moraines and in 11% of the plots is alluvial deposits.

T12 *Salix planifolia, Betula nana, Salix glauca, Vaccinium uliginosum, Arctagrostis latifolia,* feathermoss

The major species of the shrub layer are *Salix planifolia* ssp. *pulchra* (1.2 m height, 25% cover), *Salix glauca* (1.2 m height, 10% cover), *Betula nana* (1 m height, 35% cover), *Potentilla fruticosa* (.2 m height, 5% cover) and *Vaccinium uliginosum* (.2 m height, 10% cover).

The major species of the herbaceous layer are *Poa arctica* ssp. *arctica* (5% cover), *Linnaea borealis* (2% cover), *Mertensia paniculata* (3% cover), *Arctagrostis latifolia* (25% cover), *Delphinium glaucum* (3% cover) and *Festuca brachyphylla* (5% cover).

The major species of the nonvascular layer are *Pleurozium scheberi* (25% cover), *Dicranum* spp. (5% cover), *Hylocomium splendens* (25% cover), *Peltigera aphthosa* var. *leucoplebia* (3% cover), *Polytrichium* spp. (3% cover), *Aulacomnium palustre* (5% cover), *Cetraria laevigata, Stereocaulon* spp. (2% cover) and *Cladonia* spp.

This type is found at an altitude of 984 m with a 15% slope and an average aspect of 176°. The range in elevation is 716 to 1,091 m; the range in slope is 3 to 22%, and the range in aspect is zero. The bedrock geology in 50% of the plots is volcanic, in 25% of the plots is metasedimentary and in 25% of the plots is schist/gneiss. The surficial geology is bedrock.

Salix spp.

T13 *Salix reticulata, Carex membranacea, Eriophorun angustifolium, Dryas integrifolia, Sphagnum* spp.

The major species of the shrub layer in this type are *Salix lanata* ssp. *richardsonii* (1.5 m height, 5% cover), *Salix barclayi* (.6 m height, 5% cover) and *Potentilla fruticosa* (.4 m height, 5% cover).

The major species of the herbaceous layer are *Salix reticulata* (30% cover), *Dryas integrifolia* ssp. *integrifolia* (25% cover), *Carex aquatilis* (15% cover), *Carex membranacea* (15% cover), *Eriophorum angustifolium* ssp. *subarcticum* (10% cover), *Vaccinium vitis-idaea* (10% cover), *Hedysarum alpinum* (10% cover), *Anemone parviflora* (5% cover), *Equisetum sciropoides* (2% cover), *Parnassia kotzebuei* (2% cover) and *Tofieldia pusilla* (5% cover).

The major species of the nonvascular layer is *Sphagnum* spp. (35% cover).

This type is found at an altitude of 610 m on alluvial deposits. The soil is sandy. There is zero range in elevation.

T14 *Carex microglochin, Salix reticulata, Juncus castaneus, Hedysarum alpinium, Potentilla fruticosa, Sphagnum* spp.

The major species of the shrub layer are *Salix lanata* ssp. *richardsonii* (1 m height, 5% cover), *Salix barclayi* (.5 m height, 5% cover), *Potentilla fruticosa* (.5 m height, 10% cover), *Vaccinium uliginosum* (.3 m height, 5% cover) and *Sanguisorba officinalis* (1% cover).

The major species of the herbaceous layer are *Hedysarum alpinum* (25% cover), *Dryas integrifolia* ssp. *integrifolia* (10% cover), *Vaccinium* *vitis-idaea* (5% cover), *Carex scirpoidea* (10% cover), *Carex microglochin* (10% cover), *Carex membranacea* (10% cover), *Salix reticulata* (10% cover), *Juncus castaneus* ssp. *castaneus* (5% cover), *Kobresia simpliciuscula* (2% cover), *Parnassia kotzebuei* (5% cover), *Polygonum viviparum* (5% cover), *Tofieldia pusilla* (5% cover), *Saussurea angustifolia* (2% cover) and *Pedicularis verticillata* (2% cover).

The nonvascular layer is composed of *Sphagnum* spp. (25% cover).

This type is found at an altitude of 610 m on alluvial deposits. There is zero range in elevation. This type is very similar to T13, but there is 3% standing water in this type and not in T13. *Salix reticulata* has less cover value in T14 and *Juncus castaneus* appears in this type.

Vegetation Dynamics of the Study Area

The successional sequences described by Viereck (1966) and Viereck and Schandelmeir (1980) appear to be operating in the study area. Viereck and Schandelmeir state

> Taiga vegetation patterns consist of a mosaic of frequently occurring vegetation types, with a small number of individual species. The vegetation mosaic is the result of topography, climate, river meandering and flooding, parent material, presence or absence of permafrost, fire frequency and intensity, reproductive biology and autecology of individual species, and combinations of these factors.

Fire in most cases in this study resulted in a young stand which had all the species of the old mature-community plus some early successional species. M13 (1969 fire) and M10 (1946 fire) were the only fire disturbed core groups. All other plots with a fire history classified with the community of similar species association. This is due in part to similarity of species composition in plots with a fire history and plots with a history of other types of disturbance or unknown pyric disturbance. I attribute this also to the severity of fire which causes variable similarity to preburn conditions. I may have underestimated the prevalence of fire in the community types due to the lack of fire scars or good data to estimate fire history of plots. The general nature of the survey was not sensitive to the many factors and successional processes occurring. There was a limit below which the variability caused by a less severe or recent burn would not be great enough to appear significant or identifiable.

Many fires in the study area are relatively small (61%, less than 100 acres with 36% less than 9 acres) (Buskirk, 1976) and may only burn even one or two associations. Buskirk also found the highest percentage of the fires were caused by lighting (63%).

In spite of the fact that most of the burned area is attributable to large fires and that large fires are common in the tiaga, the large number of small fires helps to maintain the mosaic character of vegetation in the western portion of the study area. Fires alters temperature and moisture regimes which affects permafrost levels and vegetation patterns. Flood plain succession types and bog succession types are important contributors to the diversity of patterns in the study area. Drury (1956) describes the vegetation associations in stages from wet to dry sites in the upper Kuskokwim River region adjacent to the study area. Drury states that there is no unidirectional development. Viereck (1970) described a cycle of bog and forest where the black spruce are replaced by bog. M14 core group appeared to be a case where the bog would replace *Betula papyrifera*. Viereck (1970) also describes flood plain successional sequences. As the depth of the mineral and organic layers increases, the insulating effect of vegetation and slowly decomposing organic matter result in lowered soil temperatures, leading to reduced site productivity and diversity. Other, more localized types of succession include colonization of unstable slopes and microsuccession in areas subject to intensive frost action.

A general idealized representation of the Denali study area vegetation, its zonation and selected environmental factors is depicted in Figure 39.

Comparisons to Other Studies

The breakdown of described communities within the Preliminary Alaskan Vegetation Classification (Viereck and Dyrness, 1981) is shown in Table 8.

The revision of the classification framework resulting in the 1981 version, especially the incorporation of the tundra units into the shrubland and herbaceous vegetation formations, is substantiated by the DCA results. Shrub tundra and mat and cushion tundra show a more significant separation than shrub tundra and shrubland (Figure 7).

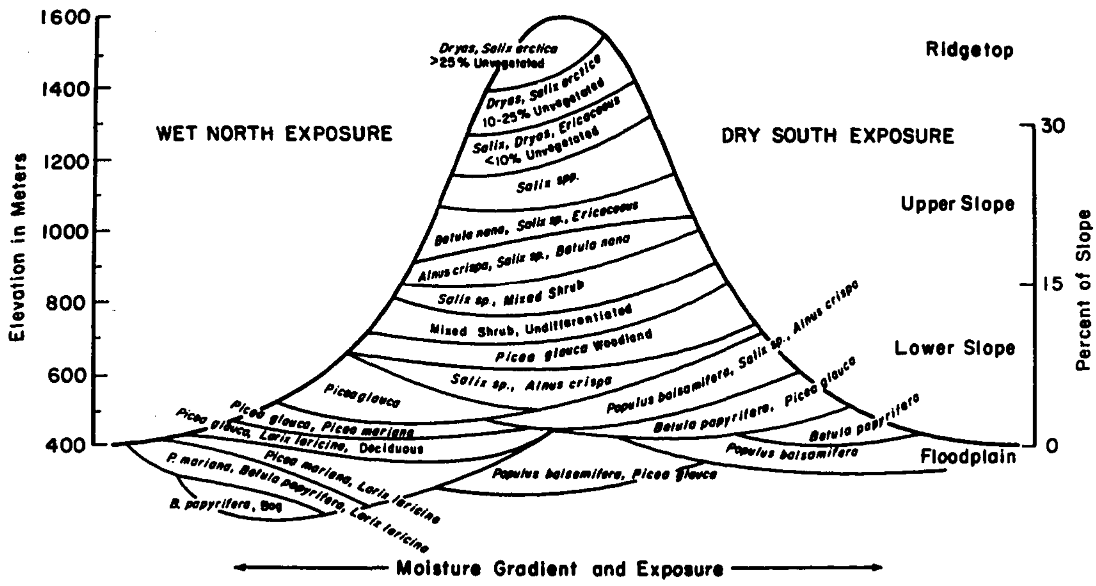


Figure 39. Diagrammatic representation of principal vegetation zones of Denali Park and Preserve in relation to topographic position.

Table 8. Hierarchic subjective classification of plant communities identified in the field using the framework presented by Viereck *et al.* (1981) and containing any additional types found. The types not previously described are indicated by an asterisk. The number of plots classified in each type at level IV is indicated.

Level I	Level II	Level III	Level IV
1. Forest	A. Conifer forest	(1) Closed conifer	a. White spruce 5
		(2) Open conifer	b. White spruce 115
			c. Black spruce 29
			d. Black spruce - white spruce 1
			e. Black spruce - tamarack 77
			Tamarack - white spruce 4
		(3) Conifer woodland	a. White spruce 1
	B. Deciduous forest	(1) Closed deciduous	b. Balsam poplar 5
			c. Paper birch 1
			Birch - aspen 1
		(2) Open deciduous	d. Balsam poplar 6
			Paper birch 1
	C. Mixed conifer and deciduous forest	(1) Closed mixed forest	a. White spruce - birch 4
			b. Aspen - spruce 1
			c. Poplar - spruce 6
			White spruce - birch - larch 3
		(2) Open mixed forest	a. Aspen - spruce 2
			White spruce - poplar 21
			White spruce - poplar - larch 6

Table 8. Continued

Level I	Level II
2. Shrubland	A. Tall Shrub
	B. Low shrub

Level III		Level IV
		White spruce - birch - larch 7
		Black spruce - birch - larch 7
		Black spruce - poplar 3
		White spruce - birch 7
(1) Closed tall shrub	a.	Alder - willow 15
		Mixed shrub 1
(2) Open tall shrub	a.	Willow 27
	b.	Alder 1
	c.	Alder - willow 6
	d.	Shrub birch - willow 7
(1) Shrub tundra	a.	Willow grass 2
	b.	Birch and ericaceous sedge 1
	c.	Mixed shrub - grass 2
	d.	Willow - undifferentiated understory 15
		Willow - ericaceous 3
		Willow - *Dryas* - sedge 4
		Birch - ericaceous - Sphagnum 2
		Birch - ericaceous - undiff. 9
		Mixed shrub - sedge 11

Table 8. Continued

Level I	Level II
2. Shrubland	C. Dwarf shrub

Level III	Level IV
	Mixed shrub - undiff. 41
	Mixed shrub - grass - lichen 6
	Mixed shrub - sedge - grass - herb 9
(2) Closed low shrub	a. Low willow 4
	b. Dwarf birch - willow 20
(3) Open low shrub	a. Willow 10
	b. Dwarf birch - willow 2
	Mixed shrub 3
	Sedge - sphagnum - ericaceous 1
(1) Mat and cushion tundra	a. *Dryas* - herb 4
	b. willow 5
	c. Mat and cushion sedge 9
	d. *Dryas* 9
	Dryas - herb - ericaceous - willow 29
	Dryas - willow - herb 19
	Grass - sedge - willow - *Dryas* - *Cassiope* 1
	Grass - ericaceous - willow - herb 2

Table 8. Continued

Level I	Level II
3. Herbaceous	A. Sedge - grass
	B. Herbs

Level III	Level IV
(1) Sedge grass - tundra	a. Wet sedge - grass meadow 1
	b. Wet sedge - herb meadow 1
(1) Wetland herbs	Fresh sedge marsh 1

Figures 40, 41, 42 and 43 illustrate the subjective classification of plots according to the Viereck and Dryness (1976) system in the DCA x-y ordination plane. Appendix II contains a table which delineates the code and abridged system necessitated by the description of communities not previously described. Appendix III presents a tabular comparison of the TWISA core groups and the subjective classification of plots typed during fieldwork using the framework presented by Viereck and Dryness (1976) and containing any additional types found but not previously described.

For the coniferous plot data the ordination distance along axis 1 follows a trend from black spruce to white spruce. This is a Level IV distinction in the Viereck and Dryness (1976) framework.

For the deciduous and mixed deciduous-coniferous plot data the ordination distance along axis 1 follows a trend from mixed paper birch-black spruce-larch, mixed paper birch-white spruce, mixed poplar-white spruce to poplar. This again is a Level IV distinction in the Viereck and Dryness (1976) framework.

For the shrub plot data the ordination distance along axis 1 follows the trend from alder, alder-willow, willow, dwarf birch-willow, to mixed shrub. This again is a Level IV distinction.

For the tundra plot data the ordination distance along axis 1 follows the sequence from open mat and cushion tundra, closed mat and cushion, willow shrub tundra to mixed shrub tundra. This also is a Level IV distinction in the Viereck and Dyrness (1976) framework.

Figure 40. Plot positions along the first two axes of variation of the DCA of the coniferous forest data (233 plots; 348 species). The plot positions are indicated by two digit numbers symbolizing the codes for levels III and IV of the PAVC which are delineated in Appendix II.

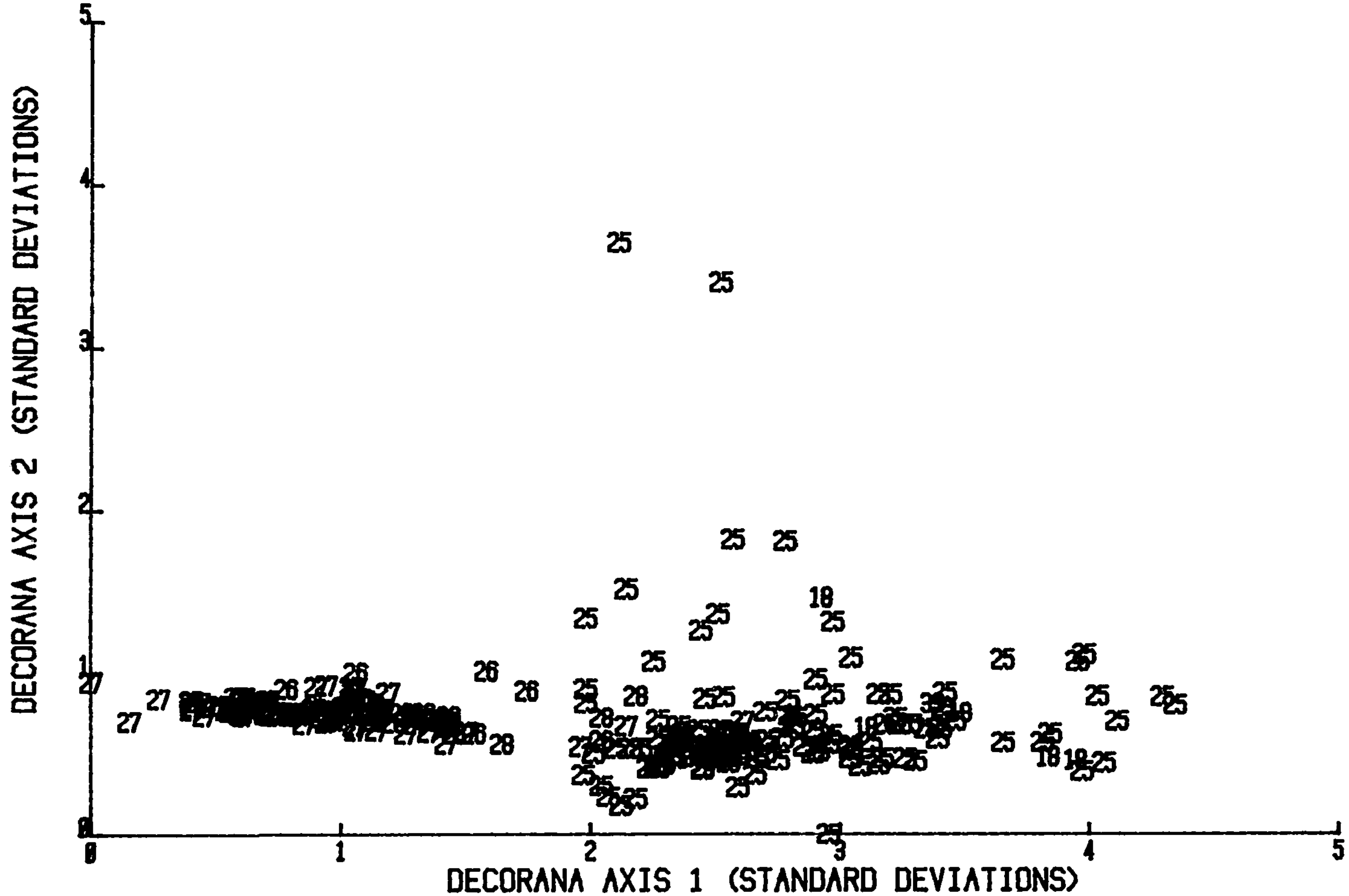

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)
0
1
2
3
4
5

Figure 41. Plot positions along the first two axes of variation of the DCA of the deciduous and mixed deciduous-coniferous forest data (80 plots; 263 species). The plot positions are indicated by three digit numbers symbolizing the codes for levels II, III and IV of the PAVC which are delineated in Appendix II.

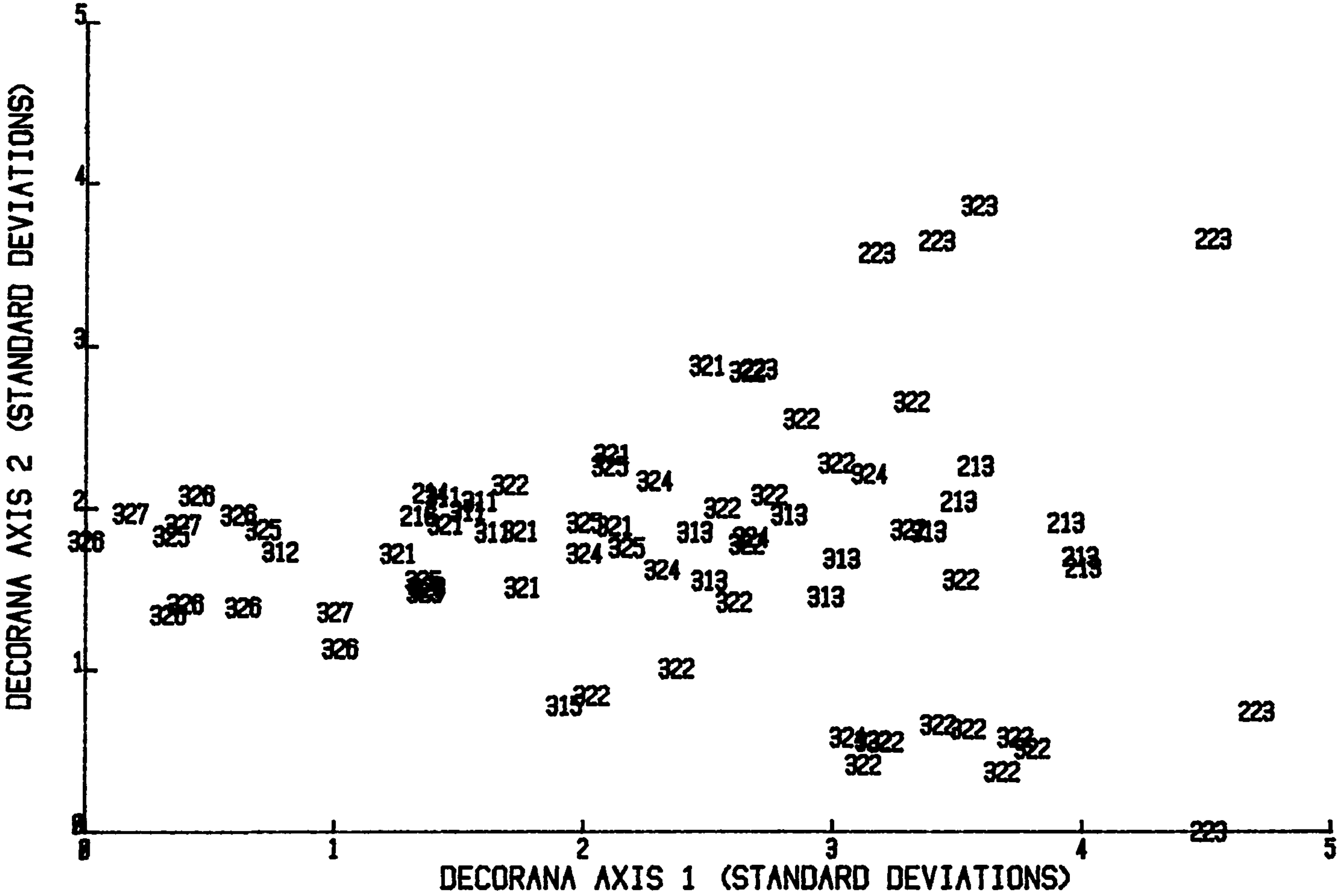

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

Figure 42. Plots positions along the first two axes of variation of the DCA ordination of the low and tall shrub data (96 plots; 344 species). The plot positions are indicated by three digit numbers symbolizing the codes for levels II, III and IV of the PAVC which are delineated in Appendix II.

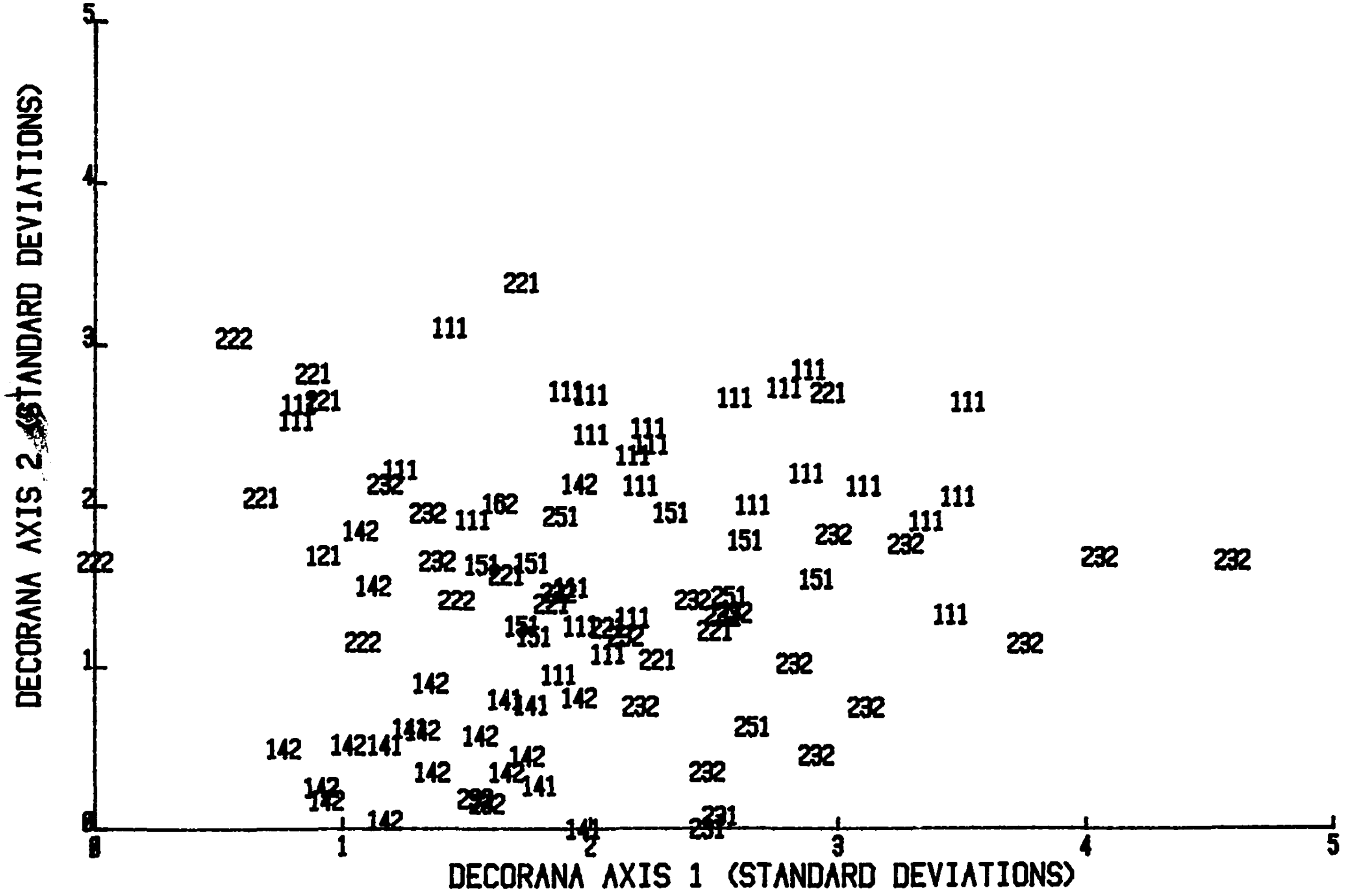
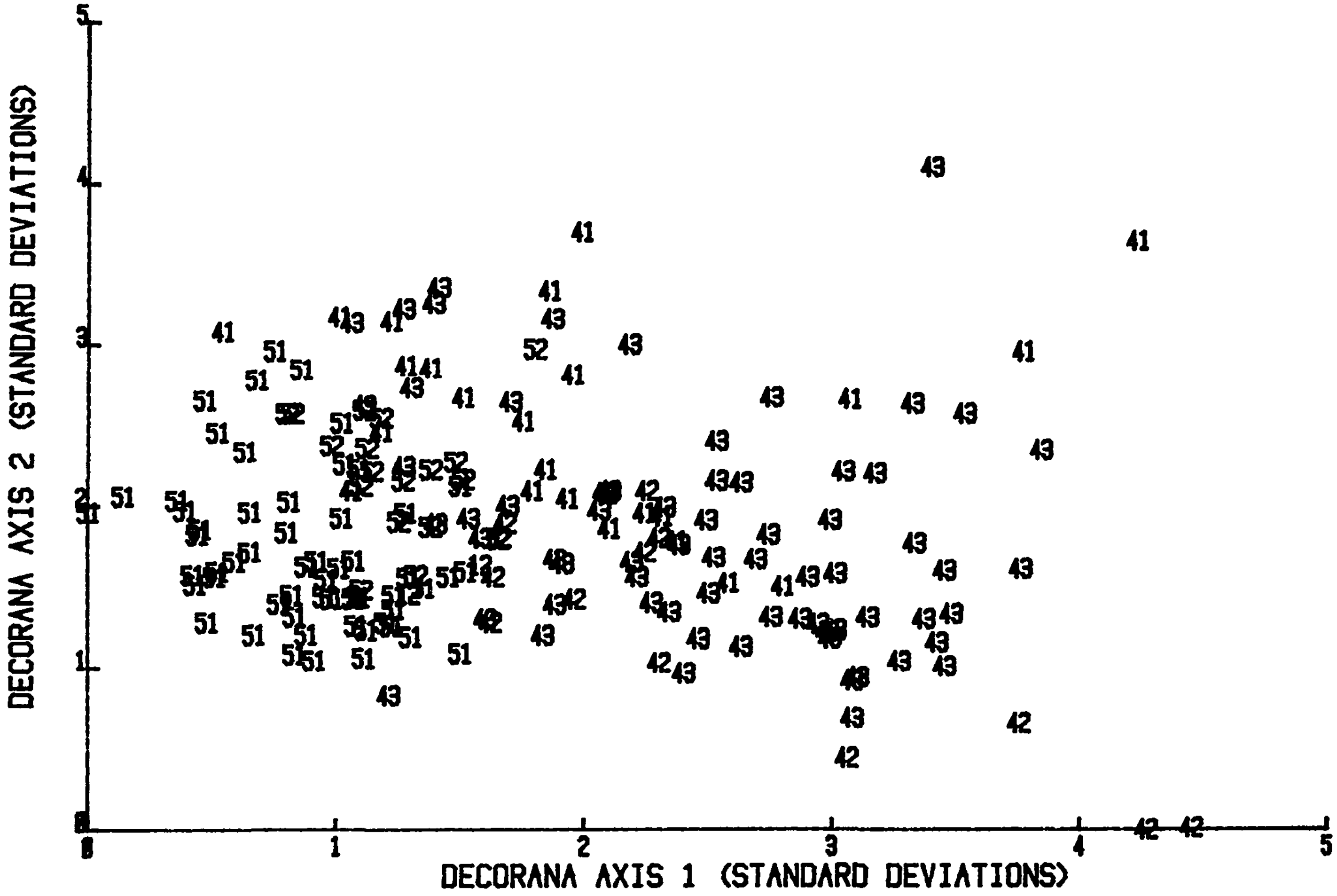

DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

Figure 43. Plot positions along the first two axes of variation of the DCA ordination of the dwarf shrub and shrub tundra data (183 plots; 404 species). The plot positions are indicated by three digit numbers symbolizing the codes for levels II and III of the PAVC which are delineated in Appendix II.


DECORANA AXIS 2 (STANDARD DEVIATIONS)
DECORANA AXIS 1 (STANDARD DEVIATIONS)

The mosaic of Viereck and Dryness (1976) types and the poor congruence when compared to the TWISA may be due to (1) the stratified random sample design which resulted in nonhomogenous types creating problems in subjective classification, (2) my inexperience and inconsistency in applying the Viereck and Dryness (1976) system and (3) the greater weight given floristics as opposed to the combination of floristics and structure used by Viereck and Dryness (1976).

Both the ordination and polythetic divisive classification technique performed give a greater emphasis to ground vegetation of the lower strata of shrubs and herbs than the canopy of trees and tall shrubs. This is due to (1) the Domin-Krajina scale of abundance used which is a combination measure of cover and frequency, (2) the relatively open nature of the canopy as opposed to the ground vegetation, (3) the greater diversity of species in the ground vegetation as opposed to the canopy of trees and shrubs, (4) the equal importance of all strata as opposed to the greater emphasis usually given to canopy strata in qualitative descriptions.

An interesting feature of the vegetation in the study area is the prevalence of mixed black spruce-larch communities. Larch (*Larix laricina* has a limited range in Alaska and is of special interest because of its abundance in the Tanana valley and rare occurrence in the Yukon Valley (Viereck, 1979). Yarie (personal communication) in his work in the Yukon-Porcupine inventory unit and Foote (1976) in her work in the Tanana highlands, Fairbanks and north, did not report this mixture. Foote and Yarie found the white spruce-black spruce mixture. Yarie suggested the prevalence of white spruce-black spruce communities in his study unit was due to the latitude of the unit. The latitude is much closer to the northern limit of black spruce than white spruce and consequently white spruce begins to occupy black spruce sites.

Viereck and Schandelmeir (1980) state that on the wettest sites, larch is associated with the black spruce. Viereck (1979) states that the mixed white spruce-black spruce communities occur toward the most northern areas, near altitudinal tree line and as ecotones between white spruce and black spruce sites.

The black spruce-white spruce and white spruce-larch-deciduous mixtures are most probably altitudinal ecotones or a successional type created by fire in the Denali study area. Strang and Johnson (1981) recognize the black and white spruce mixture as a pyric sub-climax. Viereck (1970) identified a late seral change from a mixed stand of black and white spruce to a black spruce/sphagnum community as increasing cold and soil moisture excluded white spruce. The majority of stands of the black and white spruce mixture in this study were on alluvial material or older moraines. The stands had a higher percent slope and altitude than pure black spruce types.

The even more frequent white spruce-larch-deciduous mixtures were on well-drained alluvial and glacial/fluvial floodplain deposits. The black spruce-white spruce mixtures were of older age than the white spruce-larch-deciduous mixtures. A less prevalent black spruce-paper birch-larch mixture was a fire-charred type on lacustrine deposits (M13). In the Denali Park and Preserve my explanation for the black spruce-white spruce mixture is an altitudinal tree line limit for black spruce. The spruce-larch-deciduous mixtures appear to be pyric or hydric subclimax successional types.

Larch with its faster growth rate probably has a competitive advantage over white spruce and black spruce. Larch appeared to have a shorter life span judging from the prevalence of rotten cores and the age frequency data (Figure 45). The white spruce-paper birch-larch, white spruce-poplar-larch and white spruce-larch mixtures were more frequent than the black spruce-white spruce mixture (Table 8).

The diagrams of tree age determinations (Figures 44, 45, 46, 47) provide some understanding of age distribution and predominate age classes of the study area. The data include only trees greater than 1.0 cm dbh which accounts for the low frequency of trees in the youngest age classes. Of interest is the seemingly bimodal distribution of age frequency data for white spruce. I interpret this distribution as resulting from the prevalence of young white spruce deciduous mixtures occurring on floodplains and the importance of fire in white spruce age distributions.

Foote (1976) states that most areas in interior Alaska burn when the trees are 70 to 150 years. Two variations occur in the developmental sequence after fire in interior Alaska (Foote, 1976). One develops into the forests that occur in the warm well-drained permafrost-free white spruce sites. The other develops into the forests on the mesic to wet black spruce sites where permafrost is usually present during part of the successional sequence. In the black spruce sequence, most of the

Figure 44. Age structure histogram of *Picea glauca* is illustrated for Denali Park and Preserve. The woody species were sampled in 113 different plots in the study area and the total number of individuals sampled was 624.

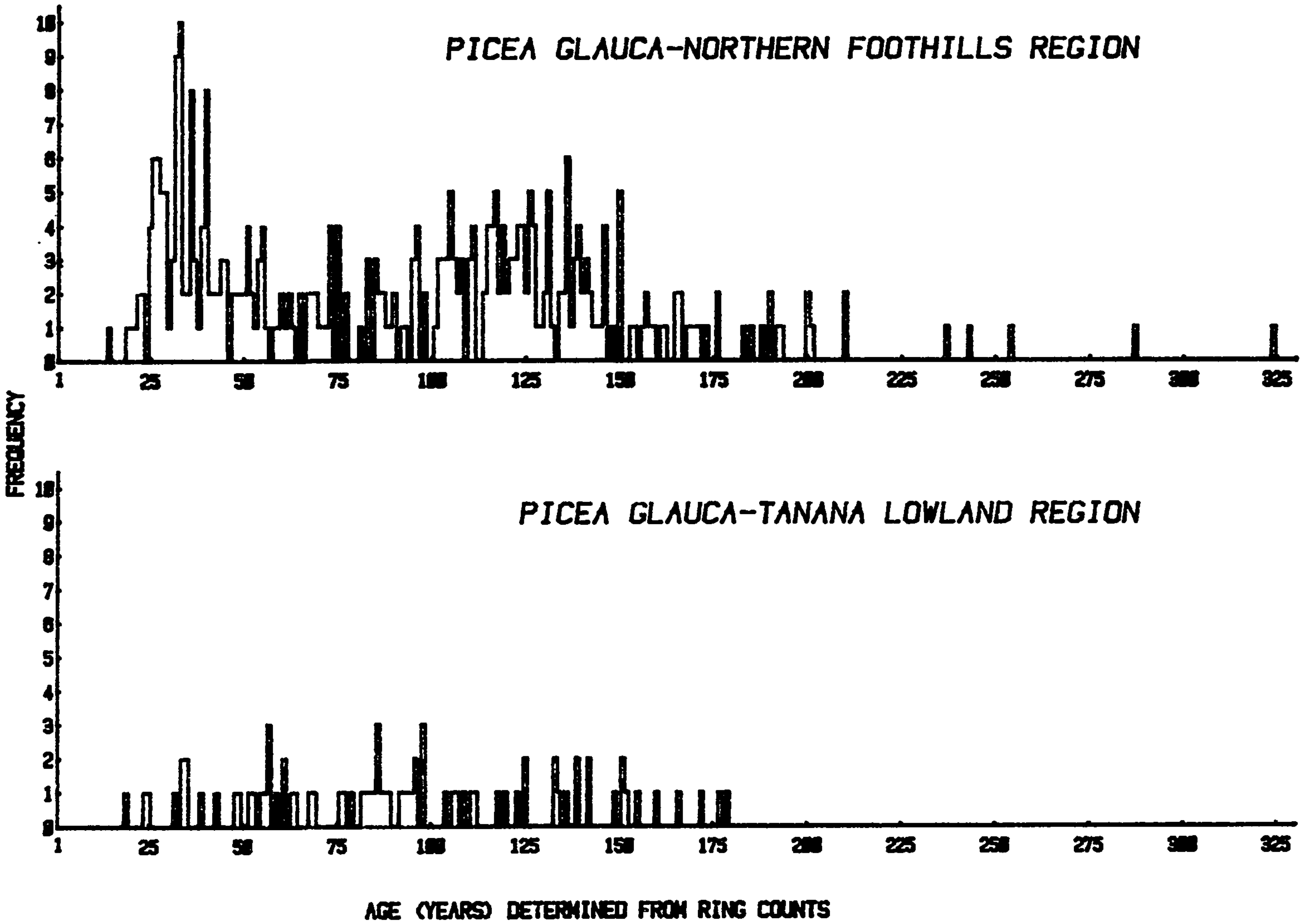

PICEA GLAUCA-NORTHERN FOOTHILLS REGION
PICEA GLAUCA-TANANA LOWLAND REGION
FREQUENCY
AGE (YEARS) DETERMINED FROM RING COUNTS

Figure 45. Age structure histogram of *Picea mariana* and *Larix laricina* is illustrated for the Tanana lowland region. The woody species were sampled in 113 different plots in the study area and the total number of individuals sampled was 624.

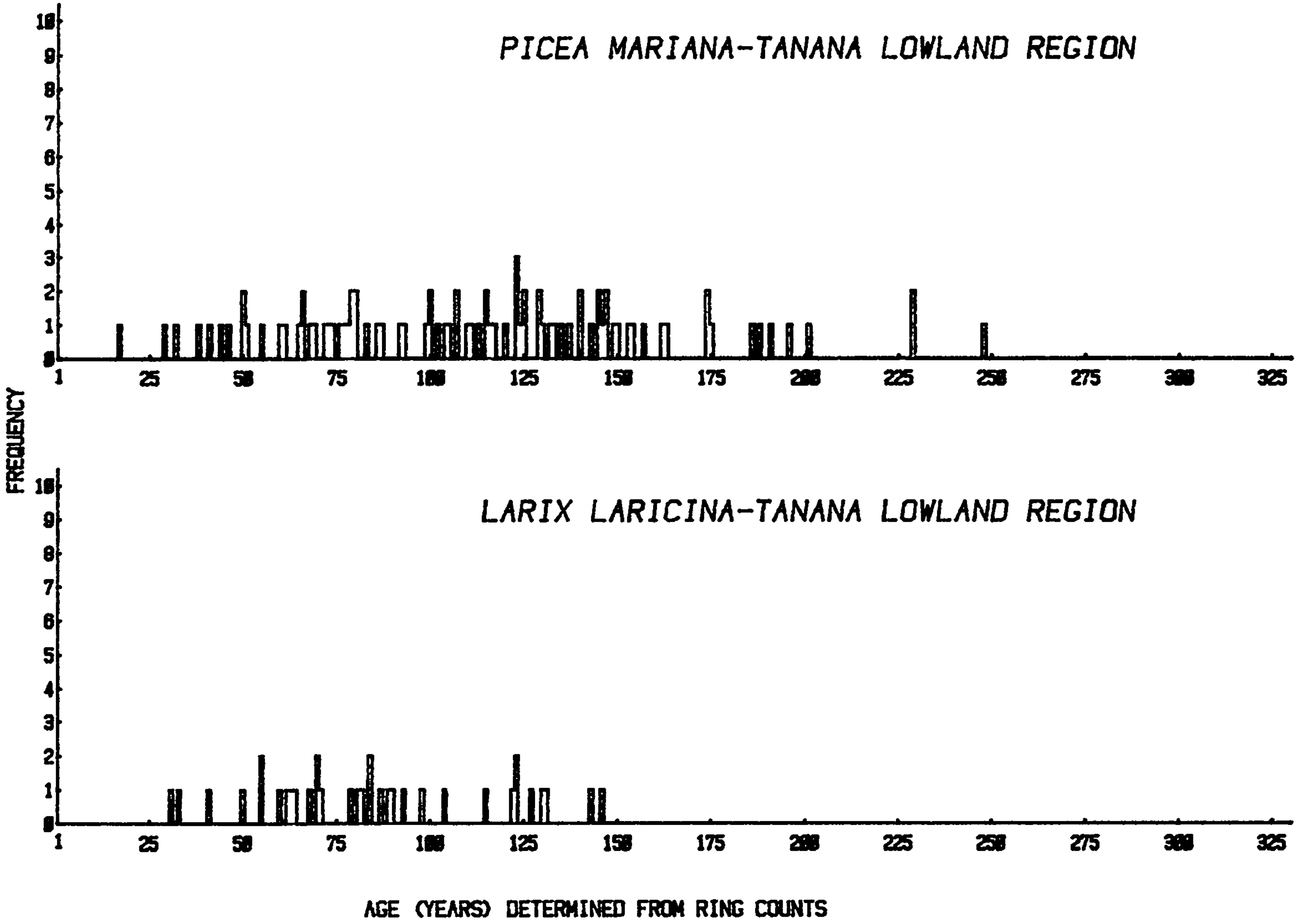

PICEA MARIANA–TANANA LOWLAND REGION
LARIX LARICINA–TANANA LOWLAND REGION
FREQUENCY
AGE (YEARS) DETERMINED FROM RING COUNTS

Figure 46. Age structure histogram of *Populus balsamifera* is illustrated for Denali Park and Preserve. The woody species were sampled in 113 different plots in the study area and the total number of individuals sampled was 624.

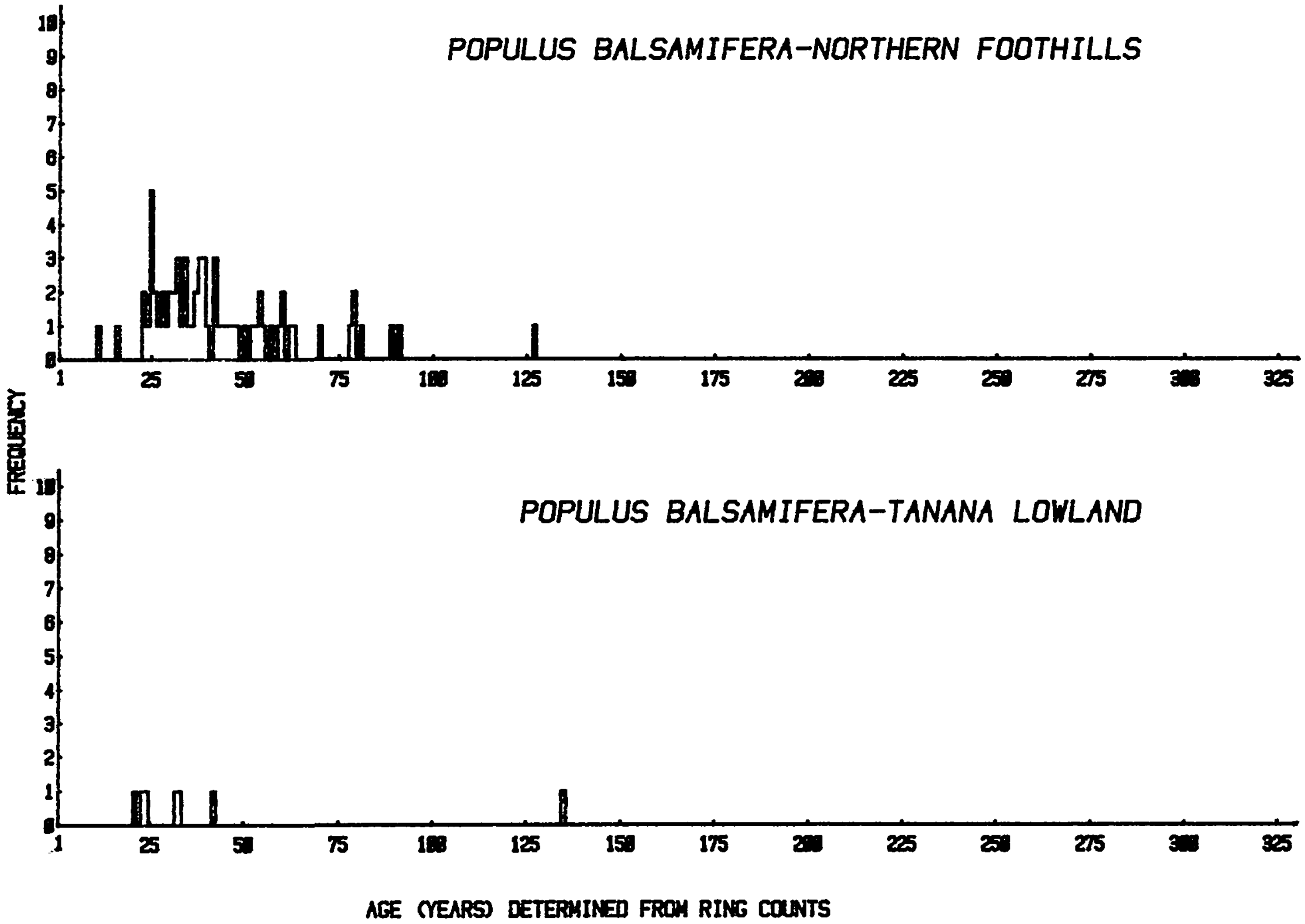
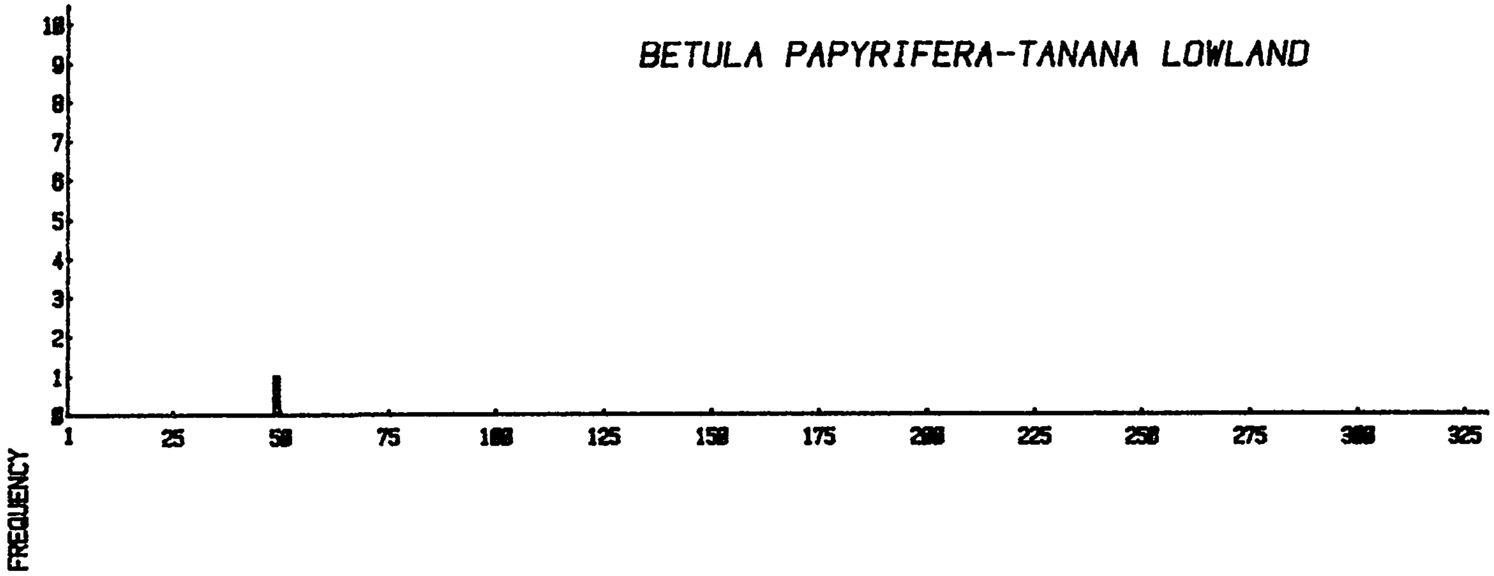

POPULUS BALSAMIFERA-NORTHERN FOOTHILLS
POPULUS BALSAMIFERA-TANANA LOWLAND
FREQUENCY
AGE (YEARS) DETERMINED FROM RING COUNTS

Figure 47. Age structure histogram of *Betula papyrifera* is illustrated for Tanana lowland region. The woody species were sampled in 113 different plots in the study area and the total number of individuals sampled was 624.



AGE (YEARS) DETERMINED FROM RING COUNTS

areas are only lightly to moderately burned, the shrub and moss layers re-establish themselves quickly and *Picea mariana* seedlings are common. Mature black spruce stands are pure black spruce which reproduce by layering or with an occasional birch or larch. Foote (1976) suggests that fire usually terminates the black spruce successional sequence before maturity is attained and frequently before the stands are 70 years old.

Revegetation of the white spruce sites differs as most of the areas are moderately to heavily burned. *Picea glauca* seed is seldom available so the light more ubiquitous seed of aspen, balsam poplar, and paper birch have more important roles. Aspen trees live less than 100 years, whereas balsam poplar and paper birch live 150 or more years. These stands may convert to spruce. Mature stands are open to closed with moderate amounts of grass and feathermoss. The older the stand and the more spruce, the more extensive the moss layer.

Densmore (1980) in the upper Dietrich Valley found peaks in *Picea glauca* age frequency at 130 to 150 years and 170 to 190 years. Yarie (in press) estimated fire cycles of 26 years for hardwoods, 36 years for black spruce and mixed spruce sites and 113 years for white spruce sites in the Porcupine-Yukon Study Unit.

My sample size is relatively small, but based on 113 different plots scattered throughout the study area, I hypothesize fire and river meandering and flooding are affecting the age distribution. The fire cycle appears to be longer than Yarie's estimates for the Porcupine-Yukon Unit (approximately 140 years for white spruce in the Denali Study Area).

Discussion of Community Types

The community types represented by the core group description is not a complete nor traditional representation of the community types of Denali National Park and Preserve. An incomplete sampling of all the vegetation types one may encounter in Denali Park and Preserve was a result of stratified random sampling design, accessibility and logistical factors. Homogenous vegetation types were not preselected for sampling. The ordination, cluster analysis and releve methods (Domin-Krajina scale) used in this study resulted in a greater emphasis on the lower strata of shrubs, herbs and nonvasculars rather than the canopy of trees and shrubs as traditionally emphasized. The classification is based on floristic characteristics as opposed to a combination of floristic and physiognomic characteristics which is the typical basis of vegetation descriptions. Therefore the community types described in this thesis have resulted from choices of methodology, and one should keep in mind that the core groups are floristic abstractions of data encountered in random plots. Therefore I shall attempt to describe subjectively the vegetation of the study area in an ecological context.

In Denali Park and Preserve, stands with closed canopies of *Picea glauca* and *Populus tremuloides* are restricted to protected well drained sites below 600 m. At higher elevations *Populus tremuloides* drops out and *Picea glauca* grows in open stands. The stands become progressively more open above 600 m and gradually change to spruce woodland at the forest tundra transition. Woodland refers to individual trees or clumps of trees scattered in a landscape covered by shrub tundra. Open spruce forests extend onto tundra along gravel river bars and well-drained, southeast-facing slopes. Stands of *Populus balsamifera* also grow along river terraces, and small trees may extend up to 1,000 m on protected south-facing slopes. Where permafrost is close to the surface open stands of stunted *Picea mariana* occur. *Picea mariana* is most frequently found in combination with *Larix laricina*, although it is also found with *Betula papyrifera* and *Populus balsamifera*. *Betula papyrifera* grows in closed stands along river terraces and on isolated slopes in the Tanana lowland and appears to be a successional state following fire. *Betula papyrifera* occurs in combination with *Populus tremuloides*, *Picea glauca*, *Larix laricina* and/or *Picea mariana*. *Larix laricina* is of special interest because of its limited range in Alaska. *Larix laricina* occurs on permafrost soils usually in combination with *Picea mariana* or *Picea glauca*.

The dominant understory species in *Picea* stands have a wide ecological amplitude and extend onto tundra as well. The most common species are *Betula nana*, *Vaccinium uliginosum*, *Vaccinium vitis-idaea*, *Empetrum nigrum* ssp. *hermaphroditum*, *Potentilla fruticosa*, *Ledum palustre* ssp. *groelandicum* and *Hylocomium splendens*. Above 600 m the following species become more abundant in *Picea* stands: *Salix reticulata*, *Salix glauca*, *Salix planifolia* ssp. *pulchra*, *Valeriana capitata*, *Polemonium acutiflorum*, *Rumex arcticus*, *Epilobium angustifolium*, *Saussurea angustifolia*, *Arctostaphylos rubra*, *Hedysarum alpinum*. The understory of the closed *Picea glauca* on river terraces is a well-developed feather-moss layer with *Alnus crispa*, *Rosa acicularis* and *Equisetum arvense*. When the *Picea glauca* stands open up on well drained river terraces, *Cladonia rangiferina*, *Cladonia alpestris*, *Cladonia mitis* and *Stereocaulon* spp. form extensive mats.

In the more poorly drained areas *Picea mariana*, *Larix laricina* and mixtures with *Betula papyrifera* occur in open stands. The understory of the wetter stands is composed of *Andromeda polifolia*, *Chamaedaphne calyculata*, *Oxyococcus microcarpus*, *Eriophorum vaginatum* and *Sphagnum* spp. In better drained areas, *Vaccinium uliginosum*, *Vaccinium vitis-idaea*, *Betula nana*, *Rubus chamaemorus*, *Carex bigelowii*, *Empetrum nigrum*, *Cladonia* spp., *Cetraria* spp. and feathermoss increase in importance.

The *Populus balsamifera* stands on river terraces have understories commonly composed of *Shepherdia canadensis*, *Salix* spp., *Betula nana*, *Arctostaphylos* spp., *Senecio lugens*, *Aster sibiricus*, *Dryas drummondi*, *Peltigera* spp., *Cladonia* spp. and *Stereocaulon* spp.

Deciduous mixes also occur along the rivers. *Picea glauca* and *Populus balsamifera* occur most frequently. Understory species include *Salix* spp., *Alnus crispa*, *Potentilla fruticosa*, *Shepherdia canadensis*, *Hedysarum alpinum*, *Epilobium angustifolium*, *Peltigera* spp. and *Hylocomium splendens*. *Picea glauca* and *Betula papyrifera* occur with understories of *Rosa acicularis*, *Vaccinium* spp., *Ledum palustre* ssp. *groenlandicum*, *Linnea borealis*, *Calamagrostis* spp., *Hycocomium splendens*, *Peltigera* spp. and *Cladonia* spp.

The distribution of forest types in the interior of Alaska is closely related to altitude, slope, aspect, drainage, permafrost and fire history (Viereck, 1973a). Discontinuous permafrost exerts an important influence on forest succession and exists in a delicate equilibrium with vegetation and topography (Drury, 1956; Viereck, 1970, 1973). North of the Alaska range permafrost is present at most sites except for warm, south-facing slopes and recently deposited river alluvium. Wildfires may also influence the position of the permafrost table by removing or stimulating the growth of the vegetation layer.

The distribution of shrubland in the study area is related to topographical factors, drainage and the position of the permafrost table.

Tall shrub occurs along river drainages, in depressions and draws. *Betula nana* is dominant on better-drained sites and is associated with *Salix* in wetter locations, where permafrost is closer to the surface. Dense stands of *Salix*, sometimes in association with *Alnus* also occur along drainages. *Betula nana* is usually associated with shrubs of *Vaccinium uliginosum*, *Salix glauca*, *Salix planifolia* ssp. *pulchra*, *Ledum palustre* and *Potentilla fruticosa*. In the herbaceous layer associates include *Vaccinium vitis-idaea*, *Empetrum nigrum*, *Salix reticulata*, *Artemisia arctica*, *Valeriana capitata*, *Petasites frigidus*, *Arctagrostis latifolia*, *Calamagrostis canadensis*, *Aconitum delphinifolium*, *Polemonium acutiflorum* and *Saxifraga hieracifolia*. In the wettest areas the shrubs are associated with tussocks of *Carex aquatilis*, *Eriophorum vaginatum* and *Eriophorum brachyantherum*. Stands of *Alnus crispa* occur on steep slopes, especially above treeline. *Spiraea beauverdiana* is an important associate.

Communities intermediate between shrub tundra and mat and cushion tundra were found. A good example is the lateral moraine of the Muldrow

Glacier between 760 and 910 m in altitude. The heterogeneous topography, substrate of mineral soil, and frost action create habitats for these types within a confined area. Other communities of shrub tundra in Denali National Park have been described by Hansen (1951) and Viereck (1956).

Shrub tundra occurs in many areas with poor drainage and a high permafrost table. The ground surface is characterized by a series of hummocks and sedge tussocks that alternate with wetter depressions. Non-sorted circles are common and are commonly filled with water. Species of *Salix* are commonly associated with these conditions. The altitudinal distribution of shrub tundra is related to winter snow cover (Glaser, 1980).

Mat and cushion tundra dominated by *Dryas octopetala* occupy exposed, well drained slopes between 1060 and 1430 m in altitude. Solifluction is active and produces a heterogeneous substrate with varying degrees of wind exposure and winter snowcover. Solifluction and frost action disrupt the vegetation cover to expose the mineral soil. The most common result of frost action is non-sorted circles, although hummocks and sorted circles or stripes are also present.

The heterogeneous substrate results in the rich diversity of species within this vegetation zone.

Dryas octopetala forms mats on both exposed and protected sites but reaches its highest cover values on the more windswept ridges. In exposed locations *Dryas* is often associated with *Silene acaulis, Loiseleuria procumbens, Diapensia lapponica, Salix arctica* and *Potentilla* *uniflora*. In depressions or terraces where snow accumulates, the vegetation is composed of *Vaccinium uliginosum*, *Empetrum nigrum*, *Rhododendron lapponicum*, *Ledum palustre* ssp. *decumbens* and *Betula glandulosa*. Also associated with the moister depressions are *Cassiope tetragona*, *Polygonum bistorta*, *Arctostaphylos alpina*, *Polygonum viviparum*, *Salix reticulata* and *Artemisia arctica*. *Luzula* spp., *Carex microchaeta*, *Carex nesophila*, *Carex scirpoidea*, *Hierochloe alpina*, *Poa alpina*, *Poa arctica* and *Phleum commutatum* are also common but seldom have appreciable cover values. Rock outcrops provide habitats for fell-field or scree-slope species such as *Saxifraga tricuspidata*, *Saxifraga bronchialis*, *Saxifraga eschscholtzii*, *Woodsia* spp., *Arnica frigida* and *Saxifraga flagellaris*.

Within this vegetational zone, wind, topography and snowcover play an important role in vegetation distribution. The close relationship between snow cover and arctic-alpine communities has been discussed by Bliss (1963), Johnson *et al.* (1066), Britton (1957), Savile (1972) and Spetzman (1959). Other factors influencing the vegetational pattern are permafrost, drainage, temperature and soil nutrients.

On ridgetops between 1,430 and 1,520 m, *Dryas octopetala* typically grows in stripe patterns or as individual mats with little cover value. *Vaccinium uliginosum*, *Empetrum nigrum*, *Betula nana* and the shrub willows are absent from this type. Associated with *Dryas* are *Arenaria chamissonis*, *Synthyris borealis*, *Chrysosplenium wrightii*, *Eritrichium aretioides*, *Papaver alaskanum*, *Saxifraga eschscholtzii*, *Saxifraga serpyllifolia*, *Saxifraga oppositifolia*, *Potentilla uniflora*, *Salix arctica*, *Salix polaris*, *Salix rotundifolia*, *Silene acaulis*, *Pedicularis kanei*, *Minuartia macrocarpa*, *Oxytropis nigrescens* and *Lagotis glauca*.

Plants on the exposed ridgetops are subject to high winds, frequent low temperatures in summer, and unseasonal snowcover. Soil is often swept away from exposed sites, leaving a substrate of scattered stones, rock outcrops, and coarse colluvium.

SUMMARY

The vegetation of the Denali National Park and Preserve encompassing in excess of 23,000 km^2 was studied. The vegetation was classified using the polythethic divisive clustering technique referred to as two-way indicator species analysis (Hill, 1979). The characterization of the vegetation and the related environmental data was accomplished by using a ordination technique termed detrended correspondence analysis (Gauch *et al.*, 1979).

Fifty-nine community-types were described in the study area ranging from blackspruce bogs to open mat and cushion tundra. The number of plant community types identified is high as to be expected in this large area of transition between major vegetation zones.

Results of the study were compared to other vegetation studies done in Alaska. Due to the stratified random selection of sample points the community types are more variable than in other typical vegetation studies (Foote, 1976). Community-types not previously described in the Preliminary Classification System for Vegetation of Alaska (Viereck and Dyrness, 1981) were encountered and described.

The white spruce-black spruce mixtures were of special interest as this mixture has only recently been reported and described by Yarie

(1980). The even more frequent white spruce-deciduous larch mixtures were previously unreported.

The explanation for the white spruce-black spruce mixture in the study area appears to be an altitudinal treeline limit for black spruce. The spruce-larch deciduous mixtures are possibly pyric or hydric sub-climax successional types.

The prevalence of the mixed shrub types is also of interest and many mixtures were identified for the first time in this study. The mixed shrub types can be explained as being ecotones of high probability due to the steep altitudinal gradient in regions of the study area. Many mixed shrub types could also be termed sub-climax successional types due to hydric and geologic phenomena. Frost-action, solifluction, permafrost, drainage, wind exposure and snow cover in combination with an heterogeneous geologically young substrate creates diverse undifferentiated mixtures.

The distributional patterns in the plot ordination of some selected environmental factors are illustrated. The soil moisture regime shows a clear gradient along the first axis which is related to elevation, slope, aspect and substrate. These factors interact to create the moisture regime as a result of incident solar radiation, temperature, drainage, and other factors. The second axis was related to structural complexity and diversity of species. The plot locations were not selected to differentiate between the environmental variables. The high variation in the distribution of plots in the x-y ordination plane suggests that factors other than topography also contribute to the composition of species. A variable history of disturbance and succession are probable causes for this variation. Overlap between community-types exists due to the broad ecological tolerances of the more important species. The data set is excellent for describing broad regional relationships.

The major vegetational pattern in Denali Park and Preserve is related to increasing climatic stress at higher altitudes. The major vegetation types and their relationship to altitude are coniferous forest (190 to 1,020 m), deciduous and mixed deciduous-coniferous forest (190 to 930 m), low and tall shrubland (460 to 1,280 m), shrub tundra (820 to 1,310 m) and mat and cushion tundra (1,060 to 1,654 m). Minor vegetation types related to local edaphic conditions include *Carex aquatilis* meadows (198 m), snow bed communities and pioneer communities.

In spite of relatively low species diversities and broad ecological tolerances, the diversity of recognizable community-types is unusually high, reflecting the topographic heterogeneity, climatic stress, and history of a variety of disturbing factors in the study area.

APPENDIX I

SURFICIAL GEOLOGY CLASSIFICATION OF PLOTS

Surficial Geology Classification of Plots

Current Glacial Moraines

Morainal systems on the surfaces of modern glaciers. In general these are sharp ridges 15 to 60 m above the surface of the neighboring clean ice. Most of the relief is due to the insulating effect of the debris mantle, which protects the underlying ice from ablation. These moraines are unvegetated except for a few types of moss and lichens.

Recent Moraines

Near the snouts of most glaciers are one or more terminal moraines which have been deposited within the last few hundred years. These moraines are unmodified by erosion and in many places are underlain by stagnant glacial ice. These deposits may include several sets of moraines: an outer older set on which grasses, mosses, and lichens are growing and an inner set, with little or no vegetation. Current glacial moraines and recent moraines are composed of angular and frost riven material that has fallen onto the glacier surface. Finer constituents comprise only a small proportion of the deposit.

Older Moraines

Two distinct groups of fresh, slightly modified moraines occur in all major valleys, and on the basis of "topographic expression and physiographic setting they are probably correlative with the Riley Creek and Carlo moraines along the Nenana River" (Wahrhaftig 1953). These moraines extend 16 to 19 km north of the mountain front in the valleys of the Herron and Foraker Rivers, 4 km from the mountains in the McKinley River valley, and 14 km in the valley of the Toklat River. Along the road in the park southeast of Wonder Lake, the moraine is composed of black slate, graywacke, banded chert and limestone, and granitic rocks. Erratics of granite are common. The topography of these moraines is not dissected by secondary streams except near major streams. Kettle holes are numerous, small and steep-sided; few have external surface drainages and are separated by sharp-crested ridges. Alignment of ridges and depressions is prominent.

I included even older moraines in this category also, which may be correlated with the Healy moraines of Wahrhaftig (1953). These moraines are much modified by dissection and mass wasting, their drainage is better integrated, slopes are gentler, the ridges are more rounded, depressions in the morainal topography are larger and fewer.

Glacial/Fluvial (undifferentiated)

Glacial outwash fans 50 km long spread into the valleys from the Alaska Range. The glacial/fluvial sediments have accumulated for at least half of the Quaternary Period (Péwé, 1975), and the total thickness is unknown but approximates 120 to 180 m in the middle Tanana lowland. The sediments bury a fairly rugged topography, the hilltops of which now are small knobs above the plain.

The northern part of the Tanana lowland is a swampy floodplain and old terraces of rivers and streams. In the western part of the lowland, fluvial deposits are covered with a thick layer of eolian sand.

Glacial Outwash

Outwash fans deposited during the different glacial advances occur beyond the terminal moraines. The outwash deposits are composed of stratified sand and gravel and many channel scars can be identified.

Fluvial Outwash

Fluvial materials on unvegetated floodplains are intermittently transported by the present streams during high water period or in the course of shifting of the braided channels. They are composed of stratified sand and gravel on the upper floodplains, grading to fine sand on the lower floodplains of the major streams.

Alluvial/Colluvial (undifferentiated)

The principal alluvial/colluvial deposits most of which are probably of recent age are:

a) vegetated stream terraces and alluvial fans composed of stratified sand and gravel of nonglacial origin but including some outwash materials of historic glacial advances;

b) talus fans and other colluvial deposits in mountain areas; and

c) valley-fill deposits in the northwestern part of the study area which are composed largely of reworked windblown silt.

Alluvial

In the vicinity of Lake Minchumina, a broad nearly level alluvial plain extends from the Foraker River south and southwest to the headwaters of the Kuskokwim and on both sides of the McKinley/Kantishna Rivers. The modern rivers have eroded the surface of the plain, cutting channels 15 to 30 m deep.

Larger areas bordering the lower part of the major streams are poorly drained and are characterized by meandering stream channels, many oxbow lakes and small thaw pits. These areas are probably underlain by alluvial silt and clay mixed and layered with peat, organic muck and windblown silt. Natural levees are bordered by swamps along these rivers and are generally composed of fine sand. In some places, as on the delta of the Foraker River which is filling the east end of Lake Minchumina, these alluvial deposits are accumulating rapidly. In other places the deposits are older (Reed, 1961).

Colluvial

Colluvial debris is made up of the rock fragments detached from the ground above and carried down the slopes mostly by gravity. Frost action is also involved with the development of colluvial deposits. Talus fans and avalanche debris in the mountain areas are examples of colluvial material.

Lacustrine

A small deposit of lacustrine clay in the Nenana River Gorge is well documented (Wahrhaftig, 1958). During the retreat of ice of the Healy glaciation, the Nenana River Gorge was occupied by a lake 0.5 km wide and 15 km long called Lake Moody. The lake deposits consist of blue and yellowish-gray, varved silty clay. Delta deposits of coarse sand and gravel interfinger with the clay.

Eolian

The surface of the alluvial plain in the vicinity of Lake Minchumina and the lower parts of the Foraker and McKinley Rivers is marked by linear and parabolic dunes which rise 15 to 45 m above the surface of the plain and by shallow straight-sided oriented lakes. The dunes of eolian origin are stabilized and are vegetated with birch, aspen and white spruce. The lakes usually have straight sides parallel with and perpendicular to the long axes of the neighboring dunes and are crudely rectangular. The lake shores are gently sloping and the level of the lakes is only slightly below the surface of the sand plain.

APPENDIX II

SUBJECTIVE VEGETATION CLASSIFICATION USED IN FIELD WORK

Appendix II. Subjective vegetation classification used in field work (Vegetation code explanation for Appendix III). Columns 1 through 4 of the vegetation number code symbolize levels I through IV respectively.

Vegetation Code	Level I	Level II	Level III	Level IV
1111	Tundra	Sedge-Grass Tundra	Wet Sedge Grass	Wet Sedge
1112				Wet Sedge-Grass
1113				Wet Sedge-Herb
1114				Wet Sedge-Shrub
1115				Wet Sedge-Grass-Shrub
1121	Tundra	Sedge-Grass Tundra	Mesic Sedge-Grass	Mesic Sedge-Grass
1122				Mesic Sedge-Herb
1123				Arctic Grass
1124				Arctic Grass-Herb
1125				Mesic Sedge-Grass-Herb
1131	Tundra	Sedge-Grass Tundra	Sedge-Shrub	Sedge-Willow
1132				Sedge-Mixed Shrub
1141	Tundra	Sedge-Grass Tundra	Sedge Mat & Cushion	Sedge-Avens
1142				Sedge-Bearberry
1211	Tundra	Herbaceous Tundra	Low Elevation Herbaceous Tundra	Seral herbs on Flood-plains
1221	Tundra	Herbaceous Tundra	Alpine Herbaceous Tundra	Herb-Sedge Snowbed
1222				Alpine Herbs
1311	Tundra	Tussock Tundra	Sedge Tussock	Cottongrass
1321			Sedge Tussock-Shrub	Sedge Tussock-Willow
1322				Sedge Tussock-Ericaceous
1323				Sedge Tussock-Mixed Shrub
1411	Tundra	Shrub Tundra	Willow	Willow-Sedge
1412				Willow-Grass
1413				Willow-Undifferentiated
1414				Willow-Ericaceous
1415				Willow-Herb-Sedge
1416				Willow-Dwarf Birch
1417				Willow-Grass-Sedge-Herb

Appendix II. Continued.

Vegetation Code	Level I	Level II
1418	Tundra	Shrub Tundra
1421	Tundra	Shrub Tundra
1422		
1423		
1424		
1425		
1431	Tundra	Shrub Tundra
1432		
1433		
1434		
1435		
1511	Tundra	Mat & Cushion Tundra
1512		
1513		
1514		
1515		
1516		
1517		
1518		
1521	Tundra	Mat & Cushion Tundra
1522		
1523		
1524		
1525		
1526		
1527		
1528		
1529		

Level III	Level IV
Willow	Willow-Herb
Birch & Ericaceous	Birch & Ericaceous-Sedge
	Birch & Ericaceous-Grass
	Birch & Ericaceous-Sphagnum
	Crowberry
	Undifferentiated Understory
Mixed Shrub	Mixed Shrub-Sedge
	Mixed Shrub-Grass
	Mixed Shrub-Undifferentiated
	Mixed Shrub-Grass-Lichen
	Mixed Shrub-Sedge-Grass-Herb
Open Mat & Cushion	Snowbed
	Avens-Lichen
	Avens-Herb
	Willow
	Ericaceous
	Avens-Herb-Ericaceous-Willow
	Avens-Willow-Herb
	Grass-Herb-Shrub
Closed Mat & Cushion	Grass-Herb-Shrub
	Mat & Cushion-Sedge
	Mat & Cushion-Grass
	Avens
	Cassiope
	Bearberry
	Grass-Sedge-Dryas-Willow-Cassiope
	Grass-Herb-Ericaceous-Willow
	Herb-Grass-Sedge

Appendix II. Continued.

Vegetation Code	Level I	Level II
2111	Shrub	Tall Shrub
2112		
2121	Shrub	Tall Shrub
2122		
2131	Shrub	Tall Shrub
2132		
2141	Shrub	Tall Shrub
2142		
2151	Shrub	Tall Shrub
2152		
2161	Shrub	Tall Shrub
2162		
2211	Shrub	Low Shrub
2212		
2221	Shrub	Low Shrub
2222		
2231	Shrub	Low Shrub
2232		
2241	Shrub	Low Shrub
2242		
2251	Shrub	Low Shrub
2252		
3111	Grass	Tall Grass
3121	Grass	Tall Grass
3122		

Level III	Level IV
Tall Willow	Open Tall Willow
	Closed Tall Willow
Alder	Open Alder
	Closed Alder
Tall Dwarf Birch	Open Tall Dwarf Birch
	Closed Tall Dwarf Birch
Alder-Willow	Open Alder-Willow
	Closed Alder-Willow
Tall Dwarf Birch-Willow	Open Tall Dwarf Birch-Willow
	Closed Tall Dwarf Birch-Willow
Tall Mixed Shrub	Open Tall Mixed Shrub
	Closed Tall Mixed Shrub
Low Dwarf Birch	Open Low Dwarf Birch
	Closed Low Dwarf Birch
Low Willow	Open Low Willow
	Closed Low Willow
Low Dwarf Birch-Willow	Open Low Dwarf Birch-Willow
	Closed Low Dwarf Birch-Willow
Low Avens-Shepherdia	Open Low Avens-Shepherdia
	Closed Low Avens-Shepherdia
Low Mixed Shrub	Open Low Mixed Shrub
	Closed Low Mixed Shrub
Bluejoint	Bluejoint
Bluejoint-Herb	Bluejoint-Fireweed
	Bluejoint-Mixed Herb

Appendix II. Continued.

Vegetation Code	Level I	Level II
3131	Grass	Tall Grass
3132		
3133		
3134		
3141	Grass	Tall Grass
3142		
3143		
3144		
3145		
3211	Grass	Mid-Grass
3212		
3213		
3221	Grass	Mid-Grass
3222		
3223		
4111	Wetlands	Fresh Water
4112		
4113		
4114		
4115		
4116		
4121	Wetlands	Fresh Water
4122		
4123		
4124		
5111	Aquatic Vegetation	Water Clear/Water Silty, Fresh Water
5112		
5113		

Level III	Level IV
Herbs	Mixed Herb
	Fireweed
	Cow Parsnip
	Ferns
Elymus	Coastal Elymus
	Elymus-Herb
	Dune-Elymus
	Inland Shore Elymus
	Dry Slope Elymus
Dry Mid-Grass	Grass-Shrub
	Dry Bluejoint
	Dry Fescue
Mesic Mid-Grass	Midgrass-Herb
	Deschampsia
	Beach Herbs
Wet Fresh Water Marsh	Sedge Marsh
	Herb Marsh
	Sedge-Herb-Shrub Marsh
	Sedge-Shrub Marsh
	Sedge-Herb Marsh
	Sedge-Sphagnum-Shrub Marsh
Wet Fresh Water Bog	Sphagnum Bog
	Sphagnum-Shrub Bog
	Moss Bog
	Sedge-Sphagnum-Shrub Bog
Ponds & Lakes	Floating and Submerged
	Emergent
	Floating-Submerged-Emergent

Appendix II. Continued.

Vegetation Code	Level I	Level II
5121	Aquatic Vegetation	Water Clear/Water Silty, Fresh Water
5122		
5123		
5124		
6111	Forest	Conifer Forest
6112		
6113		
6114		
6115		
6116		
6117		
6118		
6119		
6121	Forest	Conifer Forest
6122		
6123		
6124		
6125		
6126		
6127		
6128		
6129		
6131	Forest	Conifer Forest
6132		
6133		
6211	Forest	Deciduous Forest
6212		
6213		

Level III	Level IV
Streams/Rivers	Floating-Submerged
	Emergent
Gravel Bar	Gravel Bar Vegetated
	Gravel Bar Unvegetated
Closed Conifer	Sitka Spruce
	Sitka Spruce-Western Hemlock
	Western Hemlock
	Western Hemlock-Sitka Spruce
	Silver Fir
	Black Spruce
	White Spruce-Black Spruce
	White Spruce
	Black Spruce-Shrub
Open Conifer	Shore Pine
	Shore Pine-Western Hemlock
	Sitka Spruce-Alder
	White Spruce-Black Spruce
	White Spruce
	Black Spruce
	Black Spruce-Larch
	White Spruce-Larch
	Burnt Spruce
Woodland	Black Spruce
	White Spruce-Black Spruce
	White Spruce
Closed Deciduous	Red Alder
	Black Cottonwood
	Balsam Poplar

Appendix II. Continued.

Vegetation Code	Level I	Level II
6214		
6215		
6216		
6217		
6221	Forest	Deciduous Forest
6222		
6223		
6311	Forest	Mixed Conifer & Deciduous Forest
6312		
6313		
6314		
6315		
6316		
6317		
6321	Forest	Mixed Conifer &
6322		
6323		
6324		
6325		
6326		
6327		

Level III	Level IV
	Paper Birch
	Aspen
	Paper Birch-Aspen
	Paper Birch-Poplar
Open Deciduous	Paper Birch
	Aspen
	Poplar
Closed Mixed	White Spruce-Paper birch
	Spruce-Aspen
	Spruce-Poplar
	Black Spruce-Paper Birch
	Black Spruce-Paper Birch-Larch
	White Spruce-Paper Birch-Larch
	Spruce-Deciduous
Open Mixed	White Spruce-Paper birch-Shrub
	White Spruce-Poplar-Shrub
	White Spruce-Aspen-Shrub
	White Spruce-Poplar-Larch-Shrub
	White Spruce-Paper Birch-Larch-Shrub
	Black Spruce-Paper Birch-Larch-Shrub
	Paper Birch-Larch

APPENDIX III

TABULAR LISTING OF CORE GROUP CODE, CONSECUTIVE NUMBERS, PLOT NUMBERS AND VEGETATION TYPE CODE AS CLASSIFIED BY TWISA

Appendix III. Tabular listing of core group code, consecutive numbers (coding plots in TWISA Tables 3, 4, 5, 6), plot numbers and vegetation type code as classified by TWISA (explanation in Appendix I).

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Coniferous Core Groups C1 to C15							
C1	90	4318	6127		66	4016	6127
	94	4414	6127		71	4112	6127
					77	4214	6127
C2	187	8312	6127		79	4216	6127
	116	4713	6127		87	4315	6127
	132	4914	6127		89	4317	6127
	161	6137	6126		91	4320	6127
	207	9212	6127		93	4412	6127
	208	9213	6127		96	4416	6127
	209	9214	6127		98	4418	6127
	210	9215	6127		100	4420	6127
	211	9216	6127		109	4520	6126
	212	9217	6127		133	4915	6127
	213	9218	6127		84	4221	6127
	214	9219	6127				
				C4	102	4513	6126
C3	63	4013	6127		103	4514	6126
	67	4017	6127		104	4515	6126
	76	4213	6127		105	4516	6126
	78	4215	6127		106	4517	6126
	80	4217	6127		108	4519	6126
	81	4218	6127		146	6102	6126
	82	4219	6127		150	6105	6126
	83	4220	6127		152	6107	6126
	85	4313	6127		155	6122	6126
	86	4314	6127		206	9211	6126
	92	4411	6127		64	4014	6127
	97	4417	6127		69	4019	6127
	99	4419	6127		95	4415	6127
	101	4512	6126		185	8022	6126
	124	4812	6126		186	8311	6126
	126	4814	6126		188	8314	6126
	127	4815	6126		189	8315	6126
	128	4816	6126		205	8920	6127
	129	4817	6127		65	4015	6127
	130	4818	6127		68	4018	6127
	134	4917	6127		70	4020	6127
	183	8018	6127		74	4115	6127
	190	8316	6127		75	4119	6127
	191	8318	6127		88	4316	6127

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Coniferous Core Groups C1 to C15 (cont'd)			
C4	112	4615	6127
	113	4617	6127
	117	4714	6127
	118	4715	6126
	119	4716	6126
	120	4717	6127
	121	4718	6127
	122	4719	6127
	125	4813	6126
	144	4618	6127
C5	72	4113	6127
	73	4114	6127
	163	4920	6127
	197	8521	6127
	201	8620	6127
	203	8712	6127
	204	8919	6127
	192	8416	6126
	193	8417	6127
	194	8418	6127
	199	8617	6127
	200	8619	6127
C6	175	7612	6126
	107	4518	6126
	110	4613	6128
	111	4614	6128
	151	6106	6126
	157	6133	6125
	158	6134	6125
	163	6966	6125
	174	7609	6125
	171	7604	6125
	172	7605	6125
	170	7603	6125
C7	25	1440	6125
C8	139	5842	6125
	36	1571	6125
	37	1572	6125
	47	3142	6125
	144	5959	6125
	156	6132	6118
	123	4720	6125
	162	6138	6118
	184	8026	6133
	195	8511	6118
	321	0712	6125
	233	0060	6125
	115	4620	6127
	131	4819	6128
	145	6001	6125
	149	6104	6124
	165	6968	6125
	166	6981	6125
	177	7706	6125
	196	8512	6127
	198	8615	6126
	215	0482	6125
	229	0562	6125
C9	44	3051	6125
	45	3052	6125
	49	3432	6125
	50	3461	6125
	51	3462	6125
	52	3481	6125
	53	3482	6125
	146	6005	6125
	176	7761	6125
	180	7710	6125
	181	7711	6125
	182	7712	6125
	46	3141	6125
	54	3511	6125
	55	3512	6125
	58	3531	6125
	59	3532	6125
	138	5412	6125
	141	5953	6125

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Coniferous Core Groups C1 to C15 (cont'd)							
C9	142	5959	6125		222	0531	6125
	148	6103	6125		223	0532	6125
	153	6108	6125		225	0542	6125
	154	6109	6125		226	0551	6125
	159	6135	6125		227	0552	6125
	160	6136	6125		228	0561	6125
	167	6982	6125		5	1100	6125
	168	6983	6125		6	1110	6125
	169	7602	6128		9	1130	6125
	173	7608	6125		14	1180	6125
	216	0491	6125		16	1201	6125
	217	0492	6125		28	1460	6125
	218	0501	6125		137	5039	6125
	219	0502	6125		143	5958	6125
	220	0511	6125				
	221	0512	6125	C10	178	7707	6125
	224	0541	6125		179	7708	6125
	230	0711	6125				
	1	1041	6125	C11	30	1520	6125
	2	1042	6125				
	7	1121	6125	C12	60	3621	6125
	8	1122	6125		61	3622	6125
	10	1140	6125		18	1231	6125
	11	1150	6125		19	1232	6125
	13	1170	6125		3	1061	6125
	15	1190	6125		4	1062	6125
	17	1211	6125		12	1160	6125
	20	1400	6125		32	1541	6125
	29	1510	6125		34	1551	6125
	31	1530	6125		164	6967	6125
	33	1542	6125		202	8621	6127
	38	1581	6125				
	39	1582	6125	C13	48	3431	6125
	40	1591	6125		56	3521	6125
	41	1592	6125		57	3522	6125
	42	1651	6125		35	1552	6125
	43	1652	6125		232	0030	6125
	62	3631	6125				
	135	4918	6129	C14	26	1451	6118
	140	5952	6125		27	1452	6118
					21	1411	6125

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Coniferous Core Groups C1 to C15 (cont'd)							
C14	22	1412	6125	C15	23	1421	6125
					24	1422	6125
Deciduous/Mixed Deciduous and Coniferous Core Groups M1 to M14							
M1	8	3351	6213	M7	30	4811	6322
	9	3352	6213		38	6101	6313
					40	6965	6322
M2	10	3401	6213		66	8612	6322
					14	4111	6325
M3	65	8611	6223		15	4116	6325
					18	4212	6321
M4	51	8412	6322		25	4612	6324
	52	8413	6322		29	4712	6324
	53	8414	6322		39	6131	6313
	55	8419	6324		57	8513	6322
	56	8420	6322		60	8516	6325
	58	8514	6322		70	8811	6321
	59	8515	6322		1	1241	6322
	63	8519	6322		6	3221	6313
	64	8520	6322				
	50	8411	6223	M8	5	3150	6313
					7	3222	6313
M5	71	8812	6321		11	3641	6322
	31	4911	6223		12	3642	6322
	19	4311	6322		3	2531	6213
	32	4912	6223		4	2532	6213
	35	4919	6322				
				M9	37	5411	6322
M6	36	5221	6322		47	8111	6321
	24	4511	6322				
	27	4619	6324	M10	13	4012	6321
	28	4711	6324		68	8618	6321
	41	7705	6223		72	8911	6311
	42	7709	6313		73	8912	6311
	80	9220	6322		77	8916	6311
	69	8711	6223		78	8917	6214
					79	8918	6311
					17	4118	6324
					74	8913	6216

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Deciduous/Mixed Deciduous and Coniferous Core Groups M1 to M14 (cont'd)							
M11	2	1242	6322		75	8914	6326
	33	4913	6321		26	4616	6327
					49	8114	6326
M12	54	8415	6323				
	16	4117	6326	M13	43	8017	6326
	20	4312	6315		45	8023	6326
	34	4916	6326		48	8112	6326
	76	8915	6327		44	8019	6325
	21	4319	6312		46	8024	6327
	61	8517	6325		22	4413	6327
	62	8518	6325				
	67	8616	6325	M14	23	4421	6221
Shrub Core Groups S1 to S16							
S1	72	3671	2142		95	0932	2231
	73	3672	2142		14	1490	2232
					43	2712	2221
S2	50	2832	2112		86	6004	2251
					53	2991	2142
S3	58	3181	2142		54	2992	2142
	59	3182	2142		62	3201	2142
	61	3192	2142		63	3202	2142
					70	3411	2141
S4	51	2861	2142		93	0481	2141
	55	3091	2142		13	1470	2141
	56	3092	2142		60	3191	2142
	64	3211	2142		71	3412	2141
	65	3212	2142				
	82	0441	2141	S7	1	1001	2111
	91	0442	2141		6	1072	2251
	92	5841	2121		16	1601	2232
					17	1602	2232
S5	28	1911	2232		20	1641	2232
	29	1912	2232		23	1662	2111
					30	1921	2232
S6	3	1021	2111		31	1922	2232
	4	1022	2111		18	1631	2151
	15	1500	2232		19	1632	2151
	94	0931	2231		21	1642	2232

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Shrub Core Groups S1 to S16 (cont'd)							
S7	22	1661	2111	S12	2	1002	2111
	32	1931	2151		46	2781	2111
	33	1932	2151		47	2782	2111
	41	2690	2221		76	5004	2111
	42	2711	2221		84	5955	2111
	48	2790	2232		9	1301	2111
	52	2862	2232		10	1302	2111
	89	6961	2162		25	1772	2111
	11	1791	2221		80	5014	2111
	12	1792	2221		7	1281	2111
	26	1431	2232		8	1282	2118
	27	1432	2232				
				S13	34	1971	2151
S8	40	2581	2222		35	1972	2151
	49	3100	2222		39	2292	2111
	57	2831	2111		44	2721	2111
	5	1071	2251		36	1981	2232
	85	5957	2222		37	1982	2232
					45	2722	2111
S9	90	6984	2111		87	6013	2221
					96	0020	2111
S10	83	5843	2222				
	74	5001	2221	S14	67	3371	2232
	75	5011	2221		68	3372	2232
	77	5013	2111		69	3330	2232
	79	5002	2221				
				S15	24	1771	2111
S11	88	6014	2221		38	2291	2111
	78	5012	2111				
	81	5015	2111	S16	66	3240	2142
Tundra Core Groups T1 to T14							
T1	152	3270	1433		110	2322	1413
	153	3280	1433		115	2732	1413
					123	2851	1433
T2	154	3300	1433		124	2852	1433
					159	3501	1131
T3	88	2652	1524		20	1681	1434
	89	2321	1413		21	1682	1434

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Tundra Core Groups T1 to T14 (cont'd)							
T3	56	2041	1431	T6	12	1311	1517
	98	2411	1525		13	1312	1517
	111	2660	1412		40	1841	1517
	117	2750	1414		38	1831	1517
	165	3571	1425		39	1832	1517
					41	1842	1517
T4	24	1701	1415		44	1861	1517
	25	1702	1415		45	1862	1517
	82	2281	1524		48	1881	1517
	83	2282	1524		49	1882	1517
	84	2361	1413		50	1891	1513
	85	2302	1413		51	1892	1513
	90	2331	1413		3	1030	1517
	91	2332	1413		35	1812	1516
	96	2401	1522		47	1872	1516
	97	2402	1522		68	2211	1516
	109	2651	1524		70	2221	1517
	112	2670	1412		71	2222	1517
	118	2761	1514		72	2231	1513
	120	2770	1514		73	2232	1513
	92	2341	1514		80	2271	1517
	93	2342	1514		81	2272	1517
	102	2501	1516		189	0831	1522
					192	0901	1516
T5	58	2061	1524		96	2251	1516
	59	2062	1524		77	2252	1516
	119	2762	1514				
	101	2492	1516	T7	32	1801	1517
	103	2502	1516		33	1802	1517
	161	3541	1124		36	1821	1517
	34	1811	1516		37	1822	1517
	43	1852	1516		17	1361	1516
	46	1871	1516		18	1362	1516
	52	1901	1516		30	1781	1516
	65	2181	1516		31	1782	1516
	66	2182	1516		86	2311	1516
	69	2212	1516		99	2412	1522
	100	2491	1516		133	2700	1524
	104	2516	1516		190	0832	1522
	105	2521	1516		191	0890	1522
	106	2522	1516		193	0902	1516
	148	3231	1425		194	0911	1522

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code	Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Tundra Core Groups Tl to T14 (cont'd)							
T7	195	0912	1522		137	3071	1425
	196	0920	1527		138	3072	1425
	19	1480	1433		139	3081	1431
	54	2001	1434		140	3082	1431
	74	2241	1415		144	3161	1413
	75	2242	1415		145	3162	1413
					146	3171	1413
T8	57	2042	1431		147	3172	1413
	78	2261	1433		149	3232	1425
	79	2262	1433		150	3251	1431
	87	2312	1516		151	3252	1431
	180	7702	1434		155	3311	1433
	156	3312	1433		163	3551	1414
	162	3542	1124		164	3552	1414
	26	1711	1524		166	3581	1425
	27	1712	1524		167	3582	1425
	203	0040	1432		168	5003	1433
					169	5037	1433
T9	188	0722	1112		176	6962	1435
					177	6963	1435
T10	8	1251	1433		179	7616	1425
	9	1252	1433		182	0621	1433
	55	2002	1434		183	0622	1433
	144	2731	1413		184	0631	1433
	121	2841	1433		186	0641	1433
	122	2842	1433		187	0642	1433
	1	1011	1433		197	0970	1434
	2	1012	1433		4	1080	1433
	22	1691	1433		5	1091	1433
	23	1692	1433		6	1092	1433
	42	1857	1516		141	3110	1423
	53	1902	1516		142	3120	1421
	107	2551	1433		143	3130	1423
	108	2552	1433		174	6017	1435
	116	2740	1433		175	6111	1435
	127	2941	1433		178	6964	1435
	128	2942	1433		185	0632	1433
	129	2951	1433		199	0991	1433
	130	2952	1433		200	0992	1433
	131	2961	1433		201	0012	1435
	132	2981	1425		170	5038	1431

Appendix III. Continued.

Core Group Code	Consecutive Number	Plot Number	Vegetation Type Code
Tundra Core Groups T1 to T14 (cont'd)			
T11	173	6016	1435
	202	0014	1435
	133	3011	1431
	134	3012	1431
	135	3031	1431
	136	3032	1431
	171	6002	1432
	125	2871	1413
	126	2872	1413
T12	172	6003	1435
	28	1721	1433
	29	1722	1433
	198	0980	1413
T13	157	3491	1131
	158	3492	1131
T14	160	3502	1131

APPENDIX IV

SPECIES ABBREVIATION AND SPECIES LIST

Appendix IV. Species abbreviation and species list (codes species name in TWISA Tables 3, 4, 5, 6).

PANN HOO	*Pannaria hookeri*
NEPH SPP	*Nephroma* spp.
NEPH ART	*Nephroma articum*
NEPH EXP	*Nephroma expallidum*
PELT SPP	*Peltigera* spp.
PELT APA	*Peltigera aphthosa*
PELT TYP	*Peltigera aphthosa* var. *typica*
PELT LEU	*Peltigera aphthosa* var. *leucoplebia*
PELT CAN	*Peltigera canina*
PELT RUF	*Peltigera canina* var. *rufescens*
PELT SPU	*Peltigera canina* var. *spuria*
PELT PRA	*Peltigera praetexta*
PELT LEP	*Peltigera lepidophora*
PELT MAL	*Peltigera malacea*
PELT POL	*Peltigera polydactyla*
PELT SCA	*Peltigera scabrosa*
PELT VEN	*Peltigera venosa*
PELT HOR	*Peltigera horizontalis*
PELT HOP	*Peltigera horizontalis/polydactyla*
LOBA LIN	*Lobaria linita*
CLAD SPP	*Cladonia* spp.
CLAD CCC	*Cladonia* (subsection *Cocciferae*)
CLAD COC	*Cladonia coccifera*
CLAD DEF	*Cladonia deformis*
CLAD GON	*Cladonia gonecha*
CLAD PLE	*Cladonia pleurota*
CLAD OCH	*Cladonia* (subsection *Ochroleucae*)
CLAD CAR	*Cladonia carneola*
CLAD CYN	*Cladonia cyanipes*
CLAD BCC	*Cladonia bacilliformis/cyanipes*
CLAD THA	*Cladonia* (subsection *Thallostelides*)
CLAD GRA	*Cladonia gracilis*
CLAD GRC	*Cladonia gracilis* var. *chordals*
CLAD GRE	*Cladonia gracilis* var. *elongata*
CLAD VER	*Cladonia verticillata*
CLAD PYS	*Cladonia pyxidata*
CLAD PYX	*Cladonia pyxidata* var. *pyxidata*
CLAD PYP	*Cladonia pyxidata* var. *pocillum*
CLAD CHL	*Cladonia chlorophaea*
CLAD PHY	*Cladonia phyllophora*
CLAD COR	*Cladonia cornuta*
CLAD MIC	*Cladonia* (subsection *Microphyllae*)
CLAD SQU	*Cladonia squamosa*
CLAD MUL	*Cladonia multiformis*
CLAD SCA	*Cladonia scabriuscula*
CLAD UNE	*Cladonia* (subsection *Unciales*)
CLAD AMA	*Cladonia amaurocraea*

Appendix IV. Continued

CLAD UNC	*Cladonia uncialis*
CLAD CLA	*Cladonia* (subsection *Cladinae)*
CLAD STE	*Cladonia stellaris*
CLAD ARB	*Cladonia arbuscula*
CLAD RAN	*Cladonia rangiferina*
CLAD POD	*Cladonia* (podetia type *Cladonia* spp.)
STER SPP	*Stereocaulon* spp.
PERT SPP	*Pertusaria* spp.
ASAH CHR	*Asahinea chrysantha*
ASAH SCH	*Asahinea scholanderi*
CETR SPP	*Cetraria* spp.
CETR ERI	*Cetraria ericetorum*
CETR CUC	*Cetraria cucullata*
CETR ISL	*Cetraria islandica*
CETR NIV	*Cetraria nivalis*
CETR PIN	*Cetraria pinastri*
CETR RIC	*Cetraria richardsonii*
CETR SEP	*Cetraria sepincola*
CETR TIL	*Cetraria tilesii*
CETR LAE	*Cetraria laevigata*
CETR CHL	*Cetraria chlorophylla*
HYPO PHY	*Hypogymnia physodes*
PARM SPP	*Parmelia* spp.
PARM SUL	*Parmelia sulcata*
PARL AMB	*Parmeliopsis ambigua*
USNA SPP	*Usnaeceae* spp.
ALEC SPP	*Alectoria* spp.
ALEC NIG	*Alectoria nigricans*
ALEC OCH	*Alectoria ochroleuca*
CORN DIV	*Cornicularia divergens*
DACT RAM	*Dactylina ramulosa*
RAMA THR	*Ramalina thrausta*
THAM VER	*Thamnolia vermicularis*
USNE SPP	*Usnea* spp.
XANT CAN	*Xanthoria candelaria*
SPHS GLO	*Sphaerophorus globosus*
HEPA SPP	*Hepaticae* spp.
MARC POL	*Marchantia polymorpha*
SPHA SPP	*Sphagnum* spp.
DITR SPP	*Ditrichum* spp.
DITR FLE	*Ditrichum flexicaule*
CERA PUR	*Ceratodon purpureus*
DIST SPP	*Distichium* spp.
DIST CAP	*Distichium capillaceum*
DICR SPP	*Dicranum* spp.
DICR FUS	*Dicranum fuscescens*
TORT MUC	*Tortula mucronifolia*

Appendix IV. Continued

RHAC SPP	*Rhacomitrium* spp.
RHAC CAN	*Rhacomitrium canescens*
RHAC LAN	*Rhacomitrium lanuginosum*
BRYA SPP	*Bryaceae* spp.
MNIU THO	*Mnium thomsonii*
AULA SPP	*Aulacomnium* ssp.
AULA ACU	*Aulacomnium acuminatum*
AULA PAL	*Aulacomnium palustre*
AULA TUR	*Aulacomnium turgidium*
DREP UNC	*Drepanocladus uncinatus*
TOME NIT	*Tomenthypnum nitens*
PLEU SCH	*Pleurozium schreberi*
HYPE SPP	*Hypnaceae* spp.
HYPN SPP	*Hypnum* spp.
RHYT RUG	*Rhytidium rugosum*
HYLO SPL	*Hylocomium splendens*
POLY SPP	*Polytrichium* spp.
POLY COM	*Polytrichium commune*
POLY JUN	*Polytrichium juniperinum*
POLY STR	*Polytrichium strictum*
MUSH SPP	*Mushroom* spp.
AGAR SPP	*Agaricales* spp.
MOSS SPP	*Moss* spp.
LICH SPP	*Lichen* spp.
CYST FRS	*Cystopteris fragilis* ssp. *fragilis*
CYST DIC	*Cystopteris fragilis* ssp. *dickieana*
CYST FRA	*Cystopteris fragilis*
CYST MON	*Cystopteris montana*
WOOD ALP	*Woodsia alpina*
BYMN DRY	*Gymnocarpium dryopteris*
JUNI COM	*Juniperus communis*
LARI LAR	*Larix laricina alaskensis*
PICE SPP	*Picea* spp.
PICE GLA	*Picea glauca*
PICE MAR	*Picea mariana*
SPAR ANG	*Sparganium angustifolium*
POTA EPI	*Potamogeton epihydrus* var. *ramosus*
TRIG MAR	*Triglochin maritimum*
TRIG PAL	*Triglochin palustris*
GRAM SPP	*Gramineae* spp.
AGRO VIO	*Agropyron violaceum*
AGRO EXA	*Agrostis exarta*
ALOP AEQ	*Alopecurus aequalis*
ALOP ALP	*Alopecurus alpinus* ssp. *alpinus*
ARCT SPP	*Arctagrostis* spp.
ARCT LAL	*Arctagrostis latifolia*
ARCT LAT	*Arctagrostis latifolia* var. *latifolia*

Appendix IV. Continued

ARCT ARU	*Arctagrostis latifolia* var. *arundinacea*
ARCT POA	*Arctagrostis poaeoides*
BECK ERU	*Beckmannia erucaeformis* ssp. *baicalensis*
CALA SPP	*Calamagrostis* spp.
CALA CAN	*Calamagrostis canadensis*
CALA LAN	*Calamagrostis canadensis* ssp. *Langsdorfii*
CALA INE	*Calamagrostis inexpansa*
CALA PUR	*Calamagrostis purpurascens* ssp. *purpurascens*
CALA LAP	*Calamagrostis lapponica*
DESC CAE	*Deschampsia caespitosa*
ELYM INN	*Elymus innovatus*
FEST SPP	*Festuca* spp.
FEST ALT	*Festuca altaica*
FEST BRA	*Festuca brachyphylla*
FEST RUB	*Festuca rubra*
FEST VIV	*Festuca "vivipara"*
GLYC PUL	*Glyceria pulchella*
HIER ALP	*Hierochloe alpina*
HIER ODO	*Hierochloe odorata*
PHLE COM	*Phleum commutatum* var. *americanum*
POA SPP	*Poa* spp.
POA ALP	*Poa alpina*
POA ARC	*Poa arctica*
POA ARA	*Poa arctica* ssp. *arctica*
POA WIL	*Poa arctica* ssp. *Williamsii*
POA LON	*Poa arctica* ssp. *longiculmis*
POA GLA	*Poa glauca*
POA LAN	*Poa lanata*
POA STE	*Poa stenantha*
TRIS SPI	*Trisetum spicatum*
TRIS SPS	*Trisetum spicatum* ssp. *spicatum*
TRIS MOL	*Trisetum spicatum* ssp. *molle*
TRIS ALA	*Trisetum spicatum* ssp. *alaskanum*
CARE SPP	*Carex* spp.
CARE AQU	*Carex* ssp. *aquatilis*
CARE ATA	*Carex atrata* ssp. *atrosquamea*
CARE AUR	*Carex aurea*
CARE BIG	*Carex bigelowii*
CARE LAC	*Carex lachenalii*
CARE CAN	*Carex canescens*
CARE CAP	*Carex capillaris*
CARE COC	*Carex concinna*
CARE LUG	*Carex lugens*
CARE MED	*Carex media*
CARE MEM	*Carex membranacea*
CARE SAX	*Carex saxatilis*
CARE POD	*Carex podocarpa*

Appendix IV. Continued

CARE ROT	*Carex rotundata*
CARE SCI	*Carex scirpoidea*
CARE TEN	*Carex tenuiflora*
CARE VAG	*Carex vaginata*
CARE NES	*Carex nesophila*
CARE MIC	*Carex michrochaeta*
CARE MAG	*Carex magellanica* ssp. *irrigua*
CARE RAR	*Carex rariflora*
CARE MIN	*Carex microglochin*
CARE KRA	*Carex Krausei*
CARE NAR	*Carex nardina*
CARE ATS	*Carex atratiformis* ssp. *raymondii*
CARE WIL	*Carex Williamsii*
CARE THY	*Carex rhynchophysa*
CARE LOT	*Carex loliacea*
CARE DIO	*Carex dioica*
CARE LIM	*Carex limosa*
CARE LAS	*Carex lasiocarpa* ssp. *americana*
CARE ROS	*Carex rostrata*
KOBR SPP	*Kobresia* spp.
KOBR MYO	*Kobresia myosuroides*
KOBR SIM	*Kobresia simpliciuscula*
KOBR SIB	*Kobresia sibirica*
ERIO SPP	*Eriophorum* spp.
ERIO SUB	*Eriophorum angustifolium* ssp. *subarcticum*
ERIO TRI	*Eriophorum angustifolium* ssp. *triste*
ERIO BRA	*Eriophorum brachyantherum*
ERIO CAL	*Eriophorum callitri*
ERIO SCH	*Eriophorum Scheuchzeri* var. *Scheuchzeri*
ERIO VAG	*Eriophorum vaginatum* var. *vaginatum*
ERIO GRA	*Eriophorum gracile*
ERIO RUS	*Eriophorum russeolum* ssp. *rufescens*
JUNC SPP	*Juncus* spp.
JUNC ARC	*Juncus arcticus* ssp. *alaskanus*
JUNC CAS	*Juncus castaneus* ssp. *castaneus*
JUNC TRI	*Juncus triglumis* ssp. *albescens*
LUZU CON	*Luzula confusa*
LUZU MUS	*Luzula multiflora*
LUZU MUL	*Luzula multiflora* ssp. *multiflora* var. *frigida*
LUZU KJE	*Luzula multiflora* ssp. *multiflora* var. *Kjellmaniana*
LUZU PAR	*Luzula parviflora* ssp. *parviflora*
LUZU RUF	*Luzula rufescens*
LUZU TUN	*Luzula tundricola*
LUZU ARC	*Luzula arctica*
LLOY SER	*Lloydia serotina*
TOFI PUS	*Tofieldia pusilla*
ZYGA ELE	*Zygadenus elegans*

Appendix IV. Continued

VERA VIR	*Veratrum viride* ssp. *Eschscholtzii*
IRIS SET	*Iris setosa*
PLAT OBT	*Platanthera obtusata*
SPIR ROM	*Spiranthes Romanozoffiana*
GOOD REP	*Goodyera repens* var. *ophioides*
POPU BAL	*Populus balsamifera* ssp. *balsamifera*
POLU TRE	*Populus tremuloides*
SALI SPP	*Salix* ssp.
SALI ALA	*Salix alaxensis*
SALI AAA	*Salix alaxensis* var. *alaxensis*
SALI LON	*Salix alaxensis* var. *longistylis*
SALI ARB	*Salix arbusculoides*
SALI FUS	*Salix fuscescens*
SALI ARC	*Salix arctica*
SALI BAI	*Salix barclayi*
SALI BAR	*Salix barrattiana*
SALI BEB	*Salix bebbiana*
SALI BRA	*Salix brachycarpa* ssp. *niphoclada*
SALI HAS	*Salix hastata*
SALI GLA	*Salix glauca*
SALI MYR	*Salix myrtillifolia*
SALI PHL	*Salix phlebophylla*
SALI POL	*Salix polaris*
SALI PLA	*Salix planifolia*
SALI PUL	*Salix planifolia* ssp. *pulcra*
SALI YUK	*Salix planifolia* ssp. *pulchra* var. *yukonensis*
SALI RET	*Salix reticulata*
SALI LAN	*Salix lanata* ssp. *Richardsonii*
SALI ROT	*Salix rotundifolia*
SALI SET	*Salix setchelliana*
SALI SCO	*Salix scouleriana*
SALI MON	*Salix monticola*
MYRI GAL	*Myrica gale* var. *tomentosa*
ALNU CRI	*Alnus crispa*
BETU SPP	*Betula* spp.
BETU GLA	*Betula glandulosa*
BETU HYB	*Betula glandulosa* x *nana*
BETU OCC	*Betula occidentalis*
BETU NAN	*Betula nana* ssp. *exilis*
BETU PAP	*Betula papyrifera* ssp. *humilis*
GEOC LIV	*Geocaulon lividum*
OXYR DIG	*Oxyria digyna*
POLY SPP	*Polygonum* spp.
POLY ALA	*Polygonum alaskanum*
POLY BIS	*Polygonum bistorta*
POLY VIV	*Polygonum viviparum*
RUME ACE	*Rumex acetosa* ssp. *alpestris*

Appendix IV. Continued

RUME ARC	*Rumex arcticus*
CLAY SPP	*Claytonia* spp.
CLAY SAR	*Claytonia sarmentosa*
CLAY SCA	*Claytonia Scammaniana*
CARY SPP	Caryophyllaceae
AREN CHA	*Arenaria Chamissonis*
AREN LON	*Arenaria longipedunculata*
CERA BES	*Cerastium beeringianum*
CERA BEE	*Cerastium Beeringianum* var. *Beeringianum*
CERA GRA	*Cerastium Beeringianum* var. *grandiflorum*
MELA APE	*Melandrium apetalum* ssp. *arcticum*
MINU SPP	*Minuartia* spp.
MINU ARC	*Minuartia arctica*
MINU ROS	*Minuartia Rosii*
MINU MAC	*Minuartia macrocarpa*
MINU OBT	*Minuartia obtusiloba*
MINU RUB	*Minuartia rubella*
MINU STR	*Minuartia stricta*
MINU DAW	*Minuartia dawsonensis*
MOEH LAT	*Moehringia lateriflora*
SILE ACU	*Silene acaulis* ssp. *subacaulescens*
STEL SPP	*Stellaria* spp.
STEL CAL	*Stellaria calycantha* ssp. *interior*
STEL CRA	*Stellaria crassifolia*
STEL LAE	*Stellaria laeta*
STEL LON	*Stellaria longipes*
STEL EDW	*Stellaria Edwardsii*
STEL MON	*Stellaria monantha*
STEL ALA	*Stellaria alaskana*
WILH PHY	*Wilhelmsia physodes*
NUPH POL	*Nuphar polysepalum*
ACON DEL	*Aconitum delphinifolium*
ANEN SPP	*Anemone* spp.
ANEN DRU	*Anemone Drummondii*
ANAN MUL	*Anemone multifida*
ANEN NAR	*Anemone narcissiflora* ssp. *interior*
ANEN PAR	*Anemone parviflora*
ANEN RIC	*Anemone Richardsonii*
CALT PAL	*Caltha palustris* ssp. *arctic*
DELP GLA	*Delphinium glaucum*
RANU SPP	*Ranunculus* spp.
RANU CON	*Ranunculus confervoides*
RANU GME	*Ranunculus Gmelini* ssp. *Gmelini*
RANU PUR	*Ranunculus Gmelini* ssp. *Purshii*
RANU LAP	*Ranunculus lapponicus*
RANU NIV	*Ranunculus nivalis*
RANU PEN	*Ranunculus pennsylvanicus*

Appendix IV. Continued

THAL ALP	*Thalictrum alpinum*
THAL SPA	*Thalictrum sparsiflorum*
PAPA SPP	*Papaver* spp.
PAPA MAC	*Papaver Macounii*
PAPA ALA	*Papaver alaskanum*
PAPA LAP	*Papaver lapponicum*
CORY PAU	*Corydalis pauciflora*
CRUC SPP	Cruciferae
ARAB LYR	*Arabis lyrata* ssp. *kamchatica*
CARD BEL	*Cardamine bellidifolia*
CARD PRA	*Cardamine pratensis* ssp. *angustifolia*
CARD PUR	*Cardamine purpurea*
CARD UMB	*Cardamine umbellata*
DRAB ALP	*Draba alpina*
DRAB HIR	*Draba hirta*
DRAB NIV	*Draba nivalis*
DRAB CAE	*Draba caesia*
DRAB FLA	*Draba fladnizensis*
DRAB MAC	*Draba macrocarpa*
EUTR EDW	*Eutrema Edwardsii*
PARR NUS	*Parrya nudicaulis*
PARR INT	*Parrya nudicaulis* ssp. *interior*
PARR NUD	*Parrya nudicaulis* ssp. *nudicaulis*
RORI ISL	*Rorippa islandica* ssp. *Fernaldiana*
THAL ART	*Thlaspi arcticum*
DROS ROT	*Drosera rotundifolia*
SEDU ROS	*Sedum rosea*
CHRY WRI	*Chrysosplenium Wrightii*
PARN SPP	*Parnassia* spp.
PARN KOT	*Parnassia kotzebuei*
PARN PAL	*Parnassia palustris*
SAXI SPP	*Saxifraga* spp.
SAXI BRS	*Saxifraga bronchialis*
SAXI BRO	*Saxifraga bronchialis* spp. *Funstonii*
SAXI CAE	*Saxifraga caespitosa*
SAXI CAL	*Saxifraga calycina*
SAXI ESC	*Saxifraga Eschscholtzii*
SAXI FLA	*Saxifraga flagellaris* ssp. *setigera*
SAXI HIE	*Saxifraga hieracifolia*
SAXI HIR	*Saxifraga hirculus*
SAXI LYA	*Saxifraga Lyallii*
SAXI OPP	*Saxifraga oppositifolia* ssp. *oppositifolia*
SAXI PUN	*Saxifraga punctata* ssp. *Nelsoniana*
SAXI REF	*Saxifrage reflexa*
SAXI SER	*Saxifraga serpyllifolia*
SAXI TRI	*Saxifraga tricuspidata*
SAXI NIV	*Saxifraga nivalis*

Appendix IV. Continued

BOYK RIC	*Boykinia Richardsonii*
RIBE HUN	*Ribes hudsonianum*
RIBE TRI	*Ribes triste*
ROSA SPP	Rosaceae
DRYA SPP	*Dryas* spp.
DRYA DRU	*Dryas Drummondii*
DRYA INT	*Dryas integrifolia*
DRYA INI	*Dryas integrifolia* ssp. *integrifolia*
DRYA SYL	*Dryas integrifolia* ssp. *sylvatica*
DRYA IXS	*Dryas integrifolia* ssp. *integrifolia* hybrid with ssp. *sylvatica*
DRYA OCT	*Dryas octopetala*
DRYA OCO	*Dryas octopetala* ssp. *octopetala* var. *octopetala*
DRYA KAM	*Dryas octopetala* ssp. *octopetala* var. *kamtschatica*
DRYA ALA	*Dryas octopetala* ssp. *alaskensis*
GEUM ROS	*Geum Rosii*
POTE SPP	*Potentilla* spp.
POTE HYP	*Potentilla hyparctica*
POTE FRU	*Potentilla fruticosa*
POTE NIV	*Potentilla nivea*
POTE PAL	*Potentilla palustris*
POTE UNI	*Potentilla uniflora*
POTE MUL	*Potentilla multifida*
ROSA ACI	*Rosa acicularis*
RUBU ART	*Rubus arcticus*
RUBU STE	*Rubus arcticus* ssp. *stellatus*
RUBU ARC	*Rubus arcticus* ssp. *arcticus*
RUBU ACU	*Rubus arcticus* ssp. *acaulis*
RUBU CHA	*Rubus chamaemorus*
SANG OFF	*Sangisorba officinalis*
SANG STI	*Sanguisorba stipulata*
SPIR BEA	*Spiraea Beauverdiana*
LEGU SPP	Leguminosae
ASTR SPP	*Astragalus* spp.
ASTR ALP	*Astragalus alpinus* spp. *alpinus*
ASTR EUC	*Astragalus eucosmus* spp. *eucosmus*
ASTR ROB	*Astragalus Robbinsii* spp. *Robbinsii* var. *minor*
ASTR NUT	*Astragalus nutzotinensis*
ASTR POL	*Astragalus polaris*
ASTR UMB	*Astragalus umbellatus*
ASTR WIL	*Astragalus Williamsii*
HEDY ALP	*Hedysarum alpinum*
LUPI ARC	*Lupinus arcticus*
LUPI NOO	*Lupinus nootkatensis*
OXYT SPP	*Oxytropis* spp
OXYT CAM	*Oxytropis campestris*
OXYT BOR	*Oxytropis borealis*
OXYT MAY	*Oxytropis Maydelliana*

Appendix IV. Continued

OXYT NIG	*Oxytropis nigrescens* spp. *bryophila*
OXYT SCA	*Oxytropis Scammaniana*
GERI ERI	*Geranium erianthum*
VIOL BIF	*Viola biflora*
VIOL EPI	*Viola epipsila* ssp. *repens*
VIOL LAN	*Viola Langsdorffi*
ELEA COM	*Elaeagnus commutata*
SHEP CAN	*Shepherdia canadensis*
EPIL SPP	*Epilobium* spp.
EPIL ANA	*Epilobium anagallidifolium*
EPIL ANG	*Epilobium angustifolium*
EPIL LAT	*Epilobium latifolium*
HIPP VUL	*Hippuris vulgaris*
ANGE LUC	*Angelica lucida*
CNID CNI	*Cnidium cnidiifolium*
HERA LAN	*Heracleum lanatum*
LIGU MUT	*Ligusticum mutellinoides*
LIGU SCO	*Ligusticum scoticum*
CICU MAC	*Cicuta mackenzieana*
CORN CAN	*Cornus canadensis*
MINE UNI	*Moneses uniflora*
PYRO SPP	*Pyrola* spp.
PYRO ASA	*Pyrola asarifolia*
PYRO VIR	*Pyrola virens*
PYRO GRA	*Pyrola grandiflora*
PYRO MIN	*Pyrola minor*
PYRO SES	*Pyrola secunda*
PYRO SEC	*Pyrola secunda* ssp. *secunda*
PYRO OBT	*Pyrola secunda* ssp. *obtusata*
EMPE NIG	*Empetrum nigrum*
OXYO MIC	*Oxycoccus microcarpus*
VACC SPP	*Vaccinium* spp.
VACC UGL	*Vaccinium uliginosum*
VACC UGG	*Vaccinium uliginosum* ssp. *alpinum*
VACC UGM	*Vaccinium uliginosum* ssp. *microphyllum*
VACC VIT	*Vaccinium vitis-idaea*
CASS TET	*Cassiope tetragona*
CHAM CAL	*Chamaedaphne calyculata*
LEDU PAL	*Ledum palustre*
LEDU GRO	*Ledum palustre* ssp. *groenlandicum*
LEDU DEC	*Ledum palustre* ssp. *decumbens*
LOIS PRO	*Loiseleuria procumbens*
RHOD LAP	*Rhododendron lapponicum*
ANDR POL	*Andromeda polifolia*
ARCT SPP	*Arctostaphylos* spp.
ARCT RUB	*Arctostaphylos rubra*

Appendix IV. Continued

ARCT ALP	*Arctostaphylos alpina*
ARCT UVA	*Arctostaphylos uva-ursi*
DIAP LAP	*Diapensia lapponica*
ANDO CHA	*Androsace chamaejasme* ssp. *Lehmanniana*
DODE FRI	*Dodecatheon frigidum*
PRIM EGA	*Primula egaliksensis*
PRIM ARC	*Primula tschuktschorum* var. *arctica*
PRIM TSC	*Primula tschuktschorum* var. *tschuktschorum*
TRIE EUR	*Trientalis europaea*
TRIE EUA	*Trientalis europaea*
TRIE EUE	*Trientalis europaea* ssp. *europaea*
GENT SPP	*Gentiana* spp.
GENT ALG	*Gentiana algida*
GENT GLA	*Gentiana glauca*
GENT PRO	*Gentiana propinqua*
GENT PRP	*Gentiana propinqua* ssp. *propinqua*
GENT ARC	*Gentiana propinqua* ssp. *arctophila*
GENT PRA	*Gentiana prostrata*
SWER PER	*Swertia perennis*
MENY TRI	*Menyanthes trifoliata*
POLE ACU	*Polemonium acutiflorum*
ERIT AER	*Eritrichium aretioides*
MERT PAN	*Mertensia paniculata*
MYOS ALP	*Myosotis alpestris*
CAST ELE	*Castilleja elegans*
CAST CAU	*Castilleja caudata*
LAGO GLA	*Lagotis glauca*
PEDI SPP	*Peducularis* spp.
PEDI CAP	*Pedicularis capitata*
PEDI LAB	*Pedicularis labradorica*
PEDI KAN	*Pedicularis Kanei* ssp. *Kanei*
PEDI LAN	*Pedicularis Langsdorffii* spp. *arctica*
PEDI OED	*Pedicularis Oederi*
PEDI SUM	*Pedicularis sudetica* spp. *interior*
PEDI SUD	*Pedicularis sudetica*
PEDI VER	*Pedicularis verticillata*
SYNT BOR	*Synthyris borealis*
VERO WOR	*Veronica Wormskjoldii*
BOSC ROS	*Boschniakia rossica*
PING VUL	*Pinguicula vulgaris*
UTRI INT	*Utricularia intermedia*
UTRI VUL	*Utricularia vulgaris*
GALI BOR	*Galium boreale*
LINN BOR	*Linnaea borealis*
VIBU EDU	*Viburnum edule*
VALE CAP	*Valeriana capitata*
VALE SIT	*Valeriana stichensis*

Appendix IV. Continued

CAMP LAS	*Campanula lasiocarpa*
ACHI BOR	*Achillea borealis*
ANTE FRI	*Antennaria Friesiana*
ANTE ALA	*Antennaria Friesiana* ssp. *alaskana*
ANTE ISO	*Antennaria isolepis*
ANTE MON	*Antennaria monocephala*
ANTE PHI	*Antennaria monocephala* ssp. *philonipha*
ANTE PAL	*Antennaria pallida*
ANTE PUL	*Antennaria pulcherrima*
ARNI ALP	*Arnica alpina* ssp. *angustifolia*
ANRI LES	*Arnica Lessingii* ssp. *Lessingii*
ARTE SPP	*Artemisia* spp.
ARTE ALA	*Artemisia alaskana*
ARTE ARC	*Artemisia arctica* ssp. *arctica*
ARTE FRI	*Artemisia frigida*
ARTE TIS	*Artemisia Tilesii*
ARTE TIL	*Artemisia Tilesii* ssp. *Tilesii*
ARTE ELE	*Artemisia Tilesii* ssp. *elatior*
ARTE FUR	*Artemisia furcata*
ASTE SIB	*Aster sibiricus*
CREP NAN	*Crepis nana*
ERIG ACR	*Erigeron acris*
ERIG ELA	*Erigeron elatus*
ERIG HUM	*Erigeron humilis*
ERIG PUR	*Erigeron purpuratus*
PETA SPP	*Petasites* spp.
PETA RIF	*Petasites frigidus*
PETA HYP	*Petasites hyperboreus*
SAUS SPP	*Saussurea* spp.
SAUS ANG	*Saussurea angustifolia*
SAUS VIS	*Saussurea viscidia* var. *yukonensis*
SENE SPP	*Senecio* spp.
SENE YUK	*Senecio yukonensis*
SENE ATS	*Senecio atropurpureus*
SENE ATR	*Senecio atropurpureus* ssp. *frigidus*
SENE TOM	*Senecio atropurpureus* ssp. *tomentosus*
SENE FUS	*Senecio fuscatus*
SENE LUG	*Senecio lugens*
SENE PAU	*Senecio pauciflorus*
SENE RES	*Senecio residifolius*
SENE PAU	*Senecio pauperculus*
SENE CON	*Senecio congestus*
SOLI MUL	*Solidato multiradiata* var. *multiradiata*
TARA ALA	*Taraxacum alaskanum*
TARA KAM	*Taraxacum kamtschaticum*
LYCO SPP	*Lycopodium* spp.
LYCO ALP	*Lycopodium alpinum*

Appendix IV. Continued

LYCO ANN	*Lycopodium annotinum* ssp. *annotinum*
LYCO ANS	*Lycopodium annotinum*
LYCO PUN	*Lycopodium annotinum* var. *pungens*
LYCO MON	*Lycopodium clavatum* ssp. *monostachyon*
LYCO COM	*Lycopodium complanatum*
LYCO SEL	*Lycopodium selago*
LYCO APP	*Lycopodium appressum*
EQUI SPP	*Equisetum* spp.
EQUI ARV	*Equisetum arvense*
EQUI BOR	*Equisetum arvense* spp. *boreale*
EQUI FLU	*Equisetum fluviatile*
EQUI PRA	*Equisetum pratense*
EQUI SCI	*Equisetum scirpoides*
EQUI SYL	*Equisetum silvaticum*
EQUI VAV	*Equisetum variegatum* ssp. *variegatum*
EQUI HEM	*Equisetum hiemale*
EQUI PAL	*Euqisetum palustre*
BOTR BOR	*Botrychium boreale*

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