Vegetation and Vegetation-Environment Relationships

in a

Muskeg-Fen near Thunder Bay, Ontario.

A thesis submitted in partial fulfillment

of the requirements for the degree of Master of Science

© Maureen Victoria Ketcheson B.Sc.

Lakehead University

Thunder Bay, Ontario.

July, 1979.

Summary

This study takes place in an endangered peatland within the city of Thunder Bay Ontario. The study area, William Bog, is one of a few remaining peatlands in the Thunder Bay district which have developed on abandoned Minong phase lake basins on the north shore of Lake Superior. An inventory of vascular plants, mosses, hepatics, and ground lichens reveals that the vascular flora is richer than the moss or hepatic flora and that ground lichens are rare. Vegetation zones identified in the study area are similar to communities described for peatlands in Ontario by Jeglum et al. (1974). The study area is centered on a *Carex spp.* dominated graminoid fen which is bounded to the north and west by a conifer swamp, and to the east by a shrub rich treed bog. Ordination of vegetation data reveals that vegetation varies continuously from fen to swamp and from fen to bog. The nature and flow of groundwater is related to vegetation type such that within the fen, and to the north and west, vegetation can be classified as minerotrophic. East of the fen vegetation appears to be ombrotrophic in nature. The pH of both soil and water, calcium concentration , and conductance of water samples varies continuously along the vegetation gradients. This results in a corresponding environmental gradient which runs from strongly minerotrophic (fen) to weakly minerotrophic (conifer swamp) to the north and west, and from strongly

minerotrophic (fen) to ombrotrophic (bog) in the east.

William Bog exibits consistently higher and lower air temperatures when compared to the Thunder Bay Airport, 3 km SW , this peatland has a significantly shorter frost free period. Within the study area peats are coolest in ombrotrophic *Sphagnum spp.* hummocks east of the fen, and frost persists within these hummocks well into the growing season. West of the fen peats are warmer, likely the result of subsurface groundwater flow. There is no evidence of permafrost in the study area.

The historical and evolutionary development of William Bog is based upon the lateral expansion of Phragmites *communis* marshes through paludification of the sandy lowland basin. This resulted in two developmental sequences which are based upon the flow of groundwater within the basin. Minerotrophic communities evolve where groundwater flow is concentrated. Ombrotrophic communities develop in drier sites where *Sphagnum spp.* growth elevates the surface above the influence of groundwater. Dynamics between these communities are based upon local climatic variations during the period following initial colonization of the site, and disturbance by wildlife. The proposed development of vegetation in William Bog appears to resemble sequences proposed by several peatland studies undertaken in northern Minnesota, southern Ontario, and southern Quebec.

Acknowledgments

The author wishes to thank Dr. P. Barclay-Estrup, my thesis advisor, for suggesting William Bog as a study area. Without his guidance, interest, constructive criticism, and financial support (N.R.C. grant A6121) completion of this study would not have been possible.

I would also like to express my sincere appreciation to Mr. Wayne Blashill for his help in the field, assistance with the figures, and unfailing moral support throughout the duration of the study. I also gratefully acknowledge assistance from Mrs. Judy Commisso with the computer programs and field work.

Advice and assistance from the following people is also gratefully acknowledged;
Mr. Richard Sims, of the Great Lakes Forest Research Centre, Sault Ste. Marie, for running the Principal Components Analysis on my data; Mrs. Carol Otte, of the Lakehead University Computer Centre for help with the computer programs; Mr. Eric Wang for advice regarding the Normal Association Analysis program;
Dr. Tom Griffith and Mr. Keith Pringnitz of the Lakehead University Science Instrumentation Laboratory for determination of calcium, carbon, hydrogen, and nitrogen with the Atomic Absorbsion Spectraphotometer; Dr. E.F. Gagnon, of the Ontario Soils Testing Laboratory, for determination of ammonium and nitrates; Mr. J. Butler, of the Lakehead Science Workshop, for construction of water level measuring devices and

the point quadrat frame; Dr. John Ireland and Ms. L.Ley, of the National Museum of Canada, Ottawa, for checking my determinations of mosses and hepatics; Dr. H. Crum, of the University of Michigan, Ann Arbor, for checking my determinations of sphagnum and identifying undetermined sphagnum; Dr. Adolf Ceska, of the University of Victoria, Victoria, for checking my determinations of members of the Cyperaceae.

Finally, I would like to thank Dr.W. Graham, Dr. S. Zingel, and Dr. R. Freitag for their interest and critical review of my work.

Table of Contents

* summarized by elevation class

List of Figures, Tables, Graphs, Equations, and Plates

**

Aerial view of a portion of William Bog and the study area (circled)

Taken June 1974 scale: 1 cm on photo = 96 m on the ground

Introduction

1. The study

Peatlands occupy approximately 466,200 square kilometres of Canada's land mass (Radforth and Brawner, 1977). Within the province of Ontario alone 49% of the total land area is occupied by peatland (Ketcheson and Jeglum, 1974). Floristic and environmental descriptions of these ecosystems have been undertaken periodically throughout the past sixty years in Canada. However, inventory and description is by no means complete, and a nationally recognized classification scheme is not yet fully developed (see Zoltai, Poulett, Jeglum and Adams, 1974). Recently, there has been increased interest in peat as an energy resource, as well as in the treatment of polluted water, and as a construction material (Ruel et al., 1977). In Russia at least 300 power generating plants are fueled exclusively on peat (Moore and Bellamy, 1974). This interest in peatlands, and possible subsequent disturbance and destruction of their natural state, makes it imperative that as many are described as possible, especially in areas in immediate danger.

This study took place within William Bog, a peatland in the city of Thunder Bay, Ontario. Within the past ten years its edges have been drained and excavated for housing. Recent city expansion and proposed freeway development (Judge, 1978) will result in total destruction of this very interesting wetland, one of the few remaining in the Thunder Bay area. Consequently, this study will likely be the last botanical, ecological record of William Bog.

a) General review of peatland studies

Peatland research in North America, Great Britain, and Europe has been extensive. The result of these studies is an extremely diverse and complex variety of classification systems, each especially tailored for the region in which it was developed. The common theme, however, to all these systems is the influence of topography, climate and groundwater on the development and classification of peatland types.

In Canada Jeglum, Boissoneau and Haavisto (1974) have proposed an hierarchical classification system for the northern clay section of Ontario which stresses vegetational physiogamy and dominant vegetation. Stanek (1977) outlined muskeg regions in Canada, basing his discussion on climatic, chemical and nutrient factors.

In the western region of Canada, Rigg (1925, 1940, 1947) described some *Sphagnum spp.* bogs on the northern west coast of British Columbia and Stanek and Krajina (1964) discussed the nature of peatlands on the west coast of Vancouver Island. Lewis et al. (1926) discussed the dynamics of peatlands in central Alberta and Lewis et al. (1928) described a wide range of peatlands and wetlands in the same area.

M. Moss (1949) studied peatland development in terms of *Sphagnum spp.* hummock development and initially proposed a *Sphagnum* regeneration cycle applicable to bogs in Alberta. E. Moss (1953) described successional processes within the bog hydrosere in terms of the *Sphagnum* regeneration cycle. Recently, Vitt et al. (1975) investigated the relationship between vegetation and water and soil chemistry in patterned fens in the Swan Hills of north central Alberta and found that vegetation type and water chemistry are significantly related.

Knollenberg (1964) studied the distribution of string bogs in central Canada in relation to climate, and Zoltai (1972) described palsas and peat plateaus in central Manitoba and Saskatchewan. Jeglum (1971, 1972, 1973) investigated vegetation and vegetation-environment relationships in the Candle Lake wetlands in central Saskatchewan and found that vegetation over a wide range of wetland types was significantly related to moisture and nutrient gradients. In Manitoba, Ritchie (1957, 1959, 1962) described peatland and wetland vegetation in northern Manitoba and noted the importance of drainage and edaphic conditions upon the development of muskegs and bogs. Stringer and Stringer (1973) studied the distribution and relationship between bryophytes in a *Picea mariana* dominated bog in Bird's Hill Provincial Park in southern Manitoba.

There have been no published records of peatland vegetation ecology in northwestern Ontario encountered during this study. However, Dai et al. (1974) described water level fluctuations in a north eastern Ontario peatland near Cochrane. Sjors published major works on peat-lands associated with Hawley Lake (Sjors, 1961) and the Attawapiskat

River (Sjors, 1963), both in the remote regions of north central Ontario. It was in these works that Sjors proposed the theories of peatland development which are commonly accepted in this country. He recognized two basic types of peatland, minerotrophic sites which receive their mineral nutrients from groundwater and ombrotrophic sites which rely upon rainwater for their mineral nutrition because peat deposition has elevated their surfaces above the influence of nearby mineral rich groundwaters.

In southern Ontario Transeau (1905) described bogs and bog flora in the Huron River Valley. Dansereau and Segadas-Vianna (1952) proposed successional relationships between peatland types in Southern Ontario and Potzger (1953) and Potzger and Courtemanche (1954b) described a variety of peatlands in southern Quebec. Segadas-Vianna (1955) undertook an ecological study of a single shrub rich bog type (the *Chamaedaphne calyculata* community common to Quebec and Ontario). Gauthier (1971) studied several peat bogs in the lower St. Lawrence and Gauthier and Grandtner (1975) described successional relationships within peatlands in that area. They recognized two types of development which culminated in both minerotrophic and ombrotrophic stable communities.

In the maritime regions of Canada Porslid (1944) described a peat bog in Labrador and Allington (1961) examined the Labrador bogs in greater detail, noting specifically their physical characteristics. Pollett et al. (1970) proposed a classification for peatlands in central Newfoundland based primarily on dominant vegetation and Pollett and Bridgewater (1973) described the phytosociology of those peatlands. Bouchard et al. (1978) included a description of peatland flora and ecology in their discussion of the vascular flora of St. Barbe South district in Newfoundland.

Peatland research in the United States is primarily concentrated in the northern lake states. Some of these studies are close to the Thunder Bay Region, although it appears that no studies have been published any closer than 322 km from the study area. Conway (1949) described the bogs of central Minnesota, Janssen (1967) the bogs of northwestern Minnesota. Janssen recognized that the nature of peatland plant communities was related to their source of nutrients and that communities integrade. Heinselman (1963, 1970) investigated the relationships between peatland types in the Lake Agassiz peatlands using floristic data, water chemistry, and peat stratigraphy and determined that successional relationships in peatlands are intimately related to the flow of both ground and surface waters. He noted that minerotrophic types were dominant and true ombrotrophy was rare in his study area. Buell and Buell (1975) noted the gradual development of heath bogs where fens had once dominated on the edges of moat bogs in the Itasca Park area in Minnesota. The nature and relationship between peatland and water in the northern lake states has been investigated by Boelter and Verry (1977) demonstrating the existence of both minerotrophy and ombrotrophy. Schwintzer (1978) demonstrated that sites investigated in northern Michigan were minerotrophic fens and that within them there exists a definite relationship between the nature of the groundwater and vegetation composition.

Peatland research in Great Britain has been extensive, especially in Scotland (see Burnett (1964) chapters 9, 10, 11, 12, 14 and 15). However, an in depth survey of the literature will not be attempted here. Gorham (1956, 1967) determined that the ionic composition of ground and surface waters is intimately related to vegetation structure. Clymo (1963) noted that Sphagna have the ability to alter the ionic concentration of their immediate environment and that this plays a large role in the development of ombrotrophic peatland vegetation. Bellamy and Rieley (1967) determined that ombrotrophy can develop rapidly in *Sphagnum fuscum* hummocks. Keating (1975) studied plant community dynamics in wet heathlands. Boatman and Tomlinson (1977), in their investigation of vegetation and stratigraphy in Brishie Bog, found no evidence for a full *Sphagnum spp.* regeneration cycle (see Moss, 1953) rather, they hypothesized that there were two cycles present, one in hummocks and the other in hollows.

In Sweden and Finland peatlands are extensive and similar in many ways to those found in the Hudson's Bay lowlands of northern Ontario. Du Rietz (1949) and Sjors (1950) noted the relationship between vegetation and mineral concentration of the groundwater and originally proposed the concepts of minerotrophy and ombrotrophy. Heikurainen (1960) described the variation in wetland and peatland types in Finland and proposed successional relationships between types based upon increasing or decreasing nutrient status. In Sweden, Malmer (1962) came to similar conclusions regarding the nature of peatland vegetation-environmental relationships.

The largest area of peatlands in the world are in the U.S.S.R. and northern Europe. Although the literature is somewhat inaccessible, what is available indicates that these studies have also noted the relationship between vegetation type and the nature of the groundwater. Kulczynski (1949) classified peatlands in Poland on the basis of groundwater chemistry and developed a scheme similar to that proposed by Sjors (1950). Recently, Abramova (1975) discussed sites very similar to string bogs described by Heinselman (1963, 1970) and noted their vegetational character could be related to groundwater chemistry and flow patterns.

Studies of peatlands throughout the northern hemisphere demonstrate that vegetation and groundwater are intimately associated and that vegetation types are comparable, although not identical floristically. Within Canada peatland research has not been extensive. Within northwestern Ontario there has been no inventory of peatland types and no specific studies of vegetation and vegetation-environment relationships. Consequently, such studies in this area are necessary, especially in endangered areas such as William Bog.

This study was undertakento provide information about a peatland in northwestern Ontario, specifically William Bog on the north shore of Lake Superior, within the city limits of Thunder Bay, Ontario.

b) Terminology

The terminology associated with peatlands often varies with the location of the research project. Classification systems developed in Great Britain differ from those in Europe and those systems both share similarities and differences with the Ontario system (see Jeglum *et al*.1974). In this paper the study area was classified initially as a "muskeg-fen" using Ahti and Hepburn's (1967) definition of muskeg (see below) and Jeglum *et al*.(1974) definition of fen. As the study proceeded results indicated that the area defined as muskeg was composed of at least two distinct peatland types and that the area designated as transitional contained at least three peatland types. Thus, in order to avoid confusion regarding terminology, a list of definition of terms commonly used in this paper follows:

Peatland- terrain having some arbitrary accumulation of peat. (30 cm. *c,f.* Heinselman (1963))

Muskeg- a swampy to dryish stunted forest with a thick mat of *Sphagnum* and feather mosses underlain by rather thick peat. The ombrotrophic portions dominate. (Ahti and Hepburn, 1967). Within the study area sites dominated by *Picea mariana* over 1.5 m. in height and with a Braun-Blanquet cover of greater than 3 were initially classified as muskeg.

Fen- peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well decomposed peat near the base. They are covered by a dominant component of sedges, although grasses and reeds may be associated in local pools. *Sphagnum* is usually subordinate or absent, with the more exacting mosses being common. Often there is much low to medium shrub cover and sometimes a sparse layer of trees. The waters and peat are less acid than in bogs of the same area, and sometimes show somewhat alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually, very slow internal drainage occurs through seepage down very low gradient slopes, although sheet surface flow may occur during spring melt or periods of heavy precipitation. (Jeglum *et al*. 1974)

Transition- within the study area any site which exibits both characteristics of muskeg and fen. In these sites any *Picea mariana* present have a height of less than 1.5 m and a Braun-Blanquet cover of less than 3.

Bog- peat covered area or peat-filled depressions with a high water table and a surface carpet of mosses chiefly *Sphagnum*. The water table is at or near the surface in the spring and slightly below during the remainder of the year. The mosses often form raised hummocks that are separated by low, wet interstices. The bog surface is often raised, or if flat or level with the surrounding wetlands it is virtually isolated from mineral soil waters. Hence, the surface bog waters and peat are strongly acid and upper peat layers are extremely deficit in mineral nutrients. Peat is usually formed *in situ* under closed drainage, and oxygen saturation is very low. Although bogs are usually covered in *Sphagnum*, sedges may grow on them. They may be treed or treeless, and they are frequently characterized by a layer of ericaceous shrubs. (Jeglum *et. al*. 1974)

Swamp- wooded wetlands where standing to gently flowing waters occur seasonally or persist for long periods on the surface. Frequently there is an abundance of pools and channels indicating subsurface water flow. The substrate is usually continually waterlogged. Waters are circumneutral to moderately acid in reaction and show little deficiency in oxygen or in mineral nutrients. The substrate consists of mixtures of transported mineral and organic sediments, or peat deposited *in situ*. The vegetation cover may consists of coniferous or deciduous trees, tall shrubs, herbs and mosses. In some regions *Sphagnum* may be abundant. (Jeglum *et al*. 1974)

Vegetation zone- a unit of vegetation which is visually distinct due to its physiognomic character. Can contain repetitive patterns of vegetation such as hummocks and hollows within a single zone.

Community- a unit of relatively homogenous vegetation cover composed of integrated mixed population stands that occur as closed groupings. (Mueller-Dombois and Ellenberg, 1974)

Soil- medium in which the dominant vegetation is rooted.

Soil surface- the living surface of the moss layer, or,when a distinct moss layer is absent, the peat surface.

c.) The aims and objectives of this study are as follows:

1) To inventory vascular and bryophyte flora within the portion of William Bog in which the study takes place.

2) To classify and describe vegetation communities and gradients within the study area and to compare these results to other studies.

3) To determine the nature of relationships between climate, microclimate, groundwater, surface water, soils and vegetation communities and gradients present in the study area.

4) To propose the historical and evolutionary development of the vegetation communities and gradients in William Bog and hypothesize upon the nature of its successions, cycles and dynamics and to compare these theories to other theories of wetland development.

The above will be accomplished through the use of various methods of sampling and analysis which are standard in the sciences of climatology and plant ecology.

II. The study area

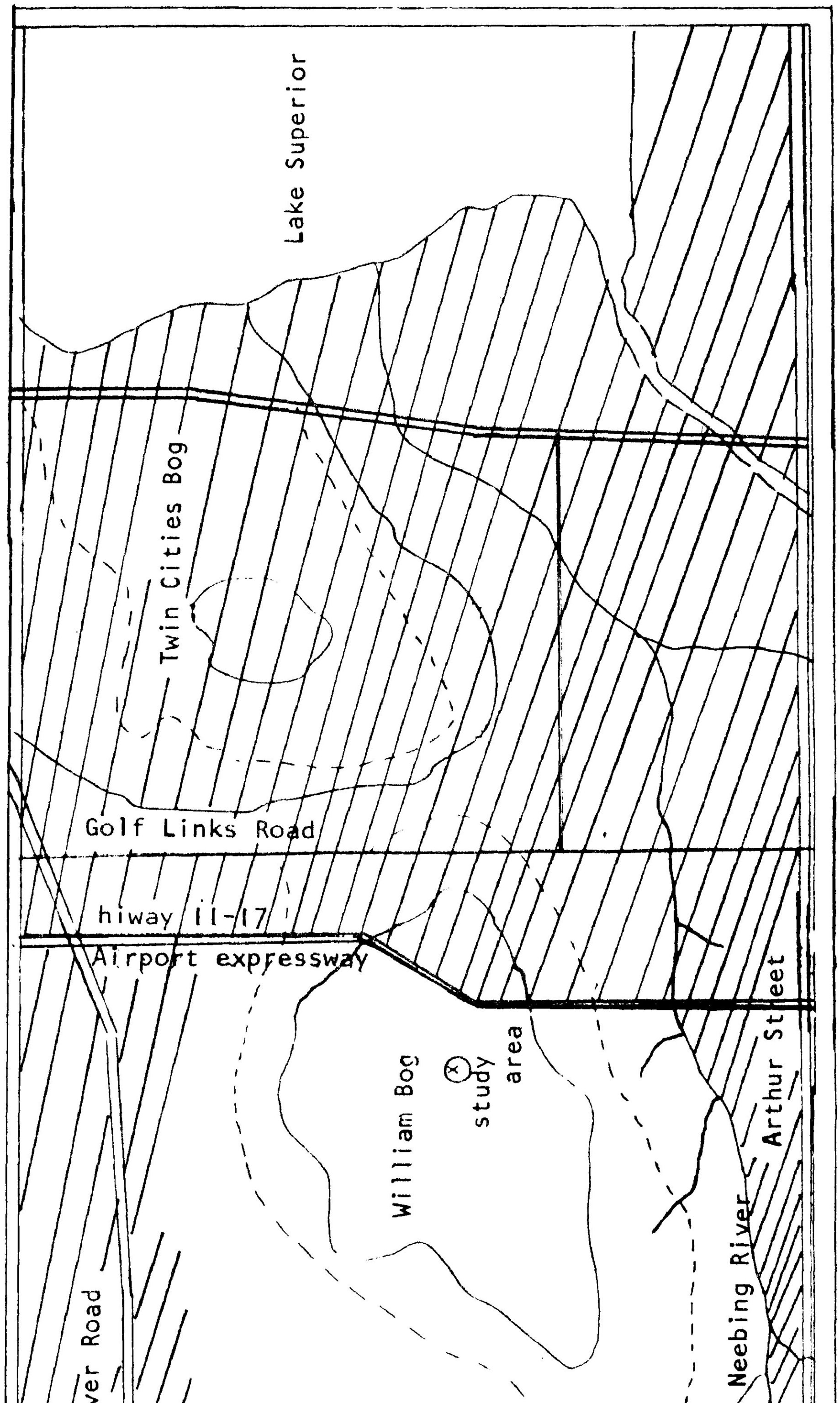
This study of peatland vegetation and environment was undertaken within the city of Thunder Bay, Ontario (population 117,000, 1979). William Bog (Anrep 1921) is located directly northwest of the airport expressway (highway 11-17) approximately 1.2 km north of the Arthur Street intersection. The study area (48° 23' 'N; 89° 18' 'W; international grid reference 16UCJ295632; elevation 199 m) is a five hectare area within the central region of William Bog (Figure 1-2 and Plate 1-1.).

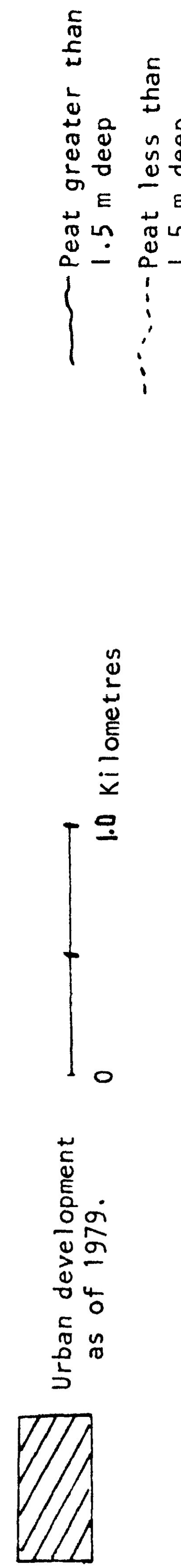
a) Geology and soils

Thunder Bay is located within the Canadian Shield. Local bedrock is late Precambrian consisting of a complex series of sedimentary and intrusive rocks classified as the Animikie and Keweenawan formations (Zoltai, 1963). The area is characterized by highlands completely encircling a central plain which gradually descends to the level of Lake Superior (184 m). Steep sided mesas, and cuestas are common. Glacial action has resulted in varying depths of unconsolidated materials which top the bedrock up to the present surface level.

Northward retreat of Pleistocene glaciation resulted in melt-waters flowing into the Superior basin forming a succession of glacially fed lakes. As glacial ice receded, water levels in the Superior Basin altered producing abandoned shorelines and exposing recent lake deposits. Flat terraces and basins which once lay beneath glacial lake waters and the rivers, streams, and peatlands occupying them constitute the youngest deposits in this region (Pye, 1962).

Figure 1-2 The location of William Bog, the study area and Highway 11-17 within a portion of Thunder Bay, Ontario, Canada. (48 23'N, 89 18'S) Elevation 199 metres. (Redrawn from Anrep, 1921)





The study area was located in a shallow sandy basin which is bounded to the west by an abandoned shoreline of the glacial Lake Minong phase of the Superior basin (Farrand, 1960). Minong occupied the Superior basin roughly 9,000 years ago. Peat deposits in William Bog have developed to an average depth of two metres (Anrep, 1921, see Results-Peat stratigraphy). Zumberge and Potzger (1956) determined that a peat bed in Wisconsin 80 cm in depth was approximately 4,000 years old. If the rates of peat deposition in this area are similar to those in Wisconsin, the two metres of peat in William Bog are likely the result of roughly 9,000 years of deposition which began soon after the waters of Lake Minong receded. However, this is an approximation of a deposition rate which has not yet been determined for this area.

b) Climate

The climate of this region is characterized by long cold winters and short cool summers. Thornthwaite (1948) classified the climate as warm microthermal on the basis of potential evapotranspiration (thermal efficiency). Mean yearly total precipitation is 738.4 mm of which 532.6 mm is rainfall. Mean snowfall per year is 222.0 cm

The mean temperature over a twelve month period is 2.2°C. There is an average of 2161.2 hours of bright sunlight in a year (Anon, 1974). Since drought effects are usually unknown in this area, control of plant growth is predominately by temperature (Hare, 1969). The mean frost free period recorded at the Thunder Bay Airport was 101 days. Lake Superior (3 km east of the study area) has an effect upon the local climate such that the area adjacent to the lake has higher relative humidities and is cooler in the spring and warmer in the fall. This modification of the climate near lakes is fully described by Geiger (1965).

c) Vegetation

William Bog lies in the transition between the Boreal Forest Region-Superior section and the Greatlakes St. Lawrence Forest Region-Quetico section (Rowe, 1972). Wetlands within the Boreal Forest Region are characterized by stands of *Picea mariana* (Mill) B.S.P. which are often found together with *Larix laricina* (Du Roi) K. Koch and *Thuja occidentalis* L. Similarly, in the Greatlakes St. Lawrence Forest Region *Picea mariana* and *Larix laricina* are common in bogs while *Thuja occidentalis* predominates along lakeshores and in rich swamps.

William Bog is developed on an oblong basin approximately 3 km by 1½ km in size (see Figure 1-2). It is predominantly forested with *Picea mariana* and *Larix laricina*. *Thuja occidentalis* is present mostly along streams within the muskeg forest and occasionally mixed into the forest cover. Ericaceous shrubs and Sphagna dominate the understorey and open areas. The central regions of the bog are crossed by a series of parallel *Carex spp.* dominated fens oriented in a south westerly direction. The extreme southwestern edge of William Bog is dominated by *Alnus spp.* and *Salix spp.* stands. These were also noted by Anrep in 1921.

The study area is at the northeastern end of one of the largest and most accessible fens within William Bog (see Figure R-4). It consists of an average stand of coniferous muskeg forest, primarily *Picea mariana* to the east of the fen, with increasing cover of *Larix laricina* north of the fen and increasing cover of *Thuja occidentalis* and *L. laricina* west of the fen. The central fen consists predominantly of *Carex* spp. with occasional stands of *Phragmites communis*. Between the fen and muskeg forest there is a band of open transitional vegetation dominated by Sphagna and ericaceous shrubs to the east and members of the Cyperaceae and *Salix spp.* to the west.

d) Disturbance

The records of disturbance in William Bog are scanty. The *Alnus spp.* and *Salix spp.* stands recorded by Anrep in 1921 in the southwest region are likely the result of fires which could have escaped from nearby agricultural areas or upland forests. Rowe and Scotter (1973) recognize *Alnus* as an understorey species which can rapidly regenerate from underground meristems when forest cover is removed by fire. Rowe et al. (1975) note that fire also encourages the growth of *Ledum groenlandicum* while inhibiting development of *Sphagnum fuscum*. The absence of stands of *Ledum groenlandicum* and the presence of well developed *Sphagnum fuscum* hummock complexes in the study area indicates that it likely has been undisturbed by fire for quite some time. Stratigraphy determined from peat cores taken in the study area shows no evidence of charcoal bands at any level in the peat bed.

An area of approximately four hectares, 500 m north of the study area has been recently cut for pulpwood (within the past five years). The effects of this clear cut upon the study area appears to have been minimal. Removal of forest cover reduces water loss by evapotranspiration and raises the water table (Penman, 1963). In a wetland such as this, a small increase in the level of the water table would have a minimal effect upon the vegetation and peat.

A gas pipeline forms the southern boundary of the study area. The pipeline appears to have interrupted drainage to the southeast diverting waters to the west down the pipeline.

The greatest disturbance suffered by William Bog is the total destruction of vegetation, peat, and wetland habitat in the southern end which is the result of city expansion, and subsequent housing subdivisions, and road construction. The southeastern end of William Bog have been obliterated by houses, roads and shopping plazas. The entire area east to the expressway is under construction. The study area and the area to the north and east have been allocated to development of a four-lane freeway and more housing.

Unfortunately, this study of William Bog will likely be the last record of wetlands occupying abandoned Minong phase lake deposits present within the city limits of Thunder Bay, Ontario.

Methods

Introduction

In order to accomplish the aims of this study two types of information were required; floristic and environmental data.

Floristic data consisted of collections and data from quadrats located along transects (see figure M-1). Environmental data included water, soils and climatic information from the study area, and climatic data from the Thunder Bay Airport meteorological station located 3 km southwest of the study area ($48^0 22'$ N, $89^0 21'$ W, elevation 200 m) see figure I-1. Stratigraphy of the study area was determined from a series of peat cores that bisected the study area (see figure M-1).

Finally, analysis of the data was accomplished through the use of computer programs, including Bray and Curtis (1957) ordination Williams and Lambert (1959) Normal Association Analysis, Principal Components Analysis (Pearce 1969), and various statistical correlations (Nie *et al.*, 1975). Additionally, data was often handsorted and simple analyses accomplished by hand calculator.

I. Vegetation

a) Collection and identification

An effort was made to obtain a complete collection of vascular plants and bryophytes (excluding epiphytic species) present within the study area, especially the area north of the pipeline. Collections

(continued on p. 17)

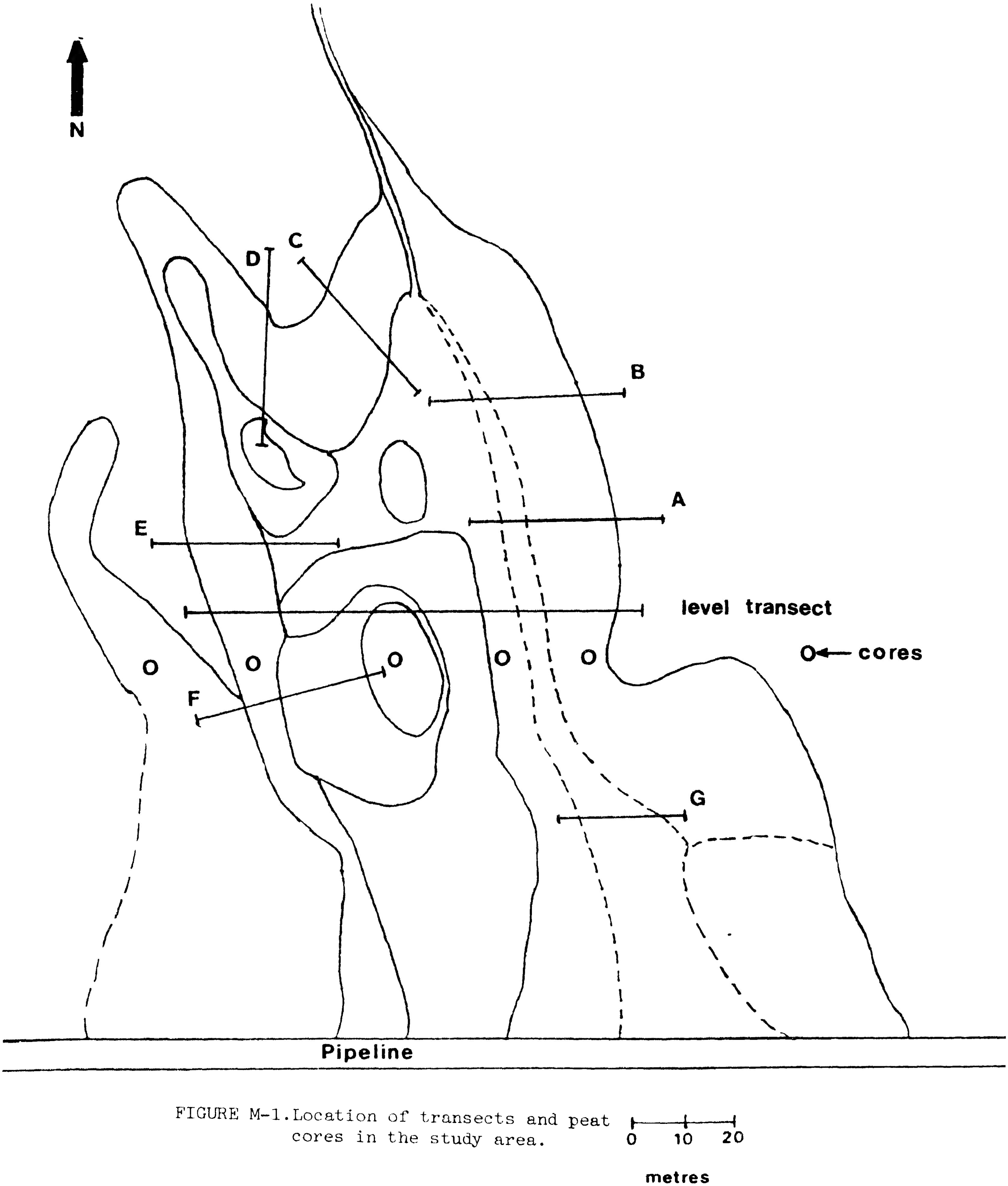


FIGURE M-1. Location of transects and peat cores in the study area.

from other areas of William Bog were made in passing and by Dr. P. Barclay-Estrup and Mr. C. E. Garton of Lakehead University.

Collected specimens were pressed and air dried (55°C) within 24 hours of collection.

Nomenclature of the vascular plants was according to Gleason and Cronquist (1963). Identifications of members of the Cyperaceae were checked by Dr. A. Češka of the University of Victoria. Nomenclature of the mosses was according to Crum (1976). Identifications of *Sphagnum* species were checked by Dr. H. Crum of the University of Michigan. Identifications of the remaining mosses and hepatics were checked by Dr. J. Ireland and Ms. L. Ley of the National Museum of Canada in Ottawa, Ontario. Nomenclature for the hepatics was according to Stotler and Crandall-Stotler (1977).

b) <u>Mapping</u>

Major vegetation zones were located on air photographs of the study area (scale: 1 cm= 96m)(NORTHWAY SURVEY CORP JOB 74 118) and then subjectively transferred to an outline map of the study area (see figure R-4). Distances to zone boundaries were checked in the field and appropriate adjustments were made to the map. The map was not intended to be a precise reproduction but, rather a diagrammatic representation of the arrangement of major, visually distinct, vegetation zones within the study area. See Plate I-1.

c) Dendrochronology

In order to determine the approximate ages of major vegetation zones within the study area (East muskeg, east transition, fen, north transition and west muskeg) several trees were felled for dendrochronological analysis. The largest tree in the zone had its diameter measured at breast height and moss level. The number of growth rings present at moss level were noted and counted on sanded discs under a dissecting microscope.

d) Point Quadrats and Microtopography

In order to obtain an objective measure of species cover (Greig-Smith 1964, Barclay-Estrup and Gimmingham 1969, Chapman 1976) point quadrats were performed over a leveled transect which bisected the study area east to west from muskeg to muskeg (see figure M-1).

1.5 m long 20 mm × 40 mm stakes were driven into the peat at 3 metre intervals. Constant elevation was maintained along the stakes through use of a surveyors transit and rod. Point quadrats were taken at 10 cm intervals over the 111 metre transect by lowering a sharpened steel pin through an aluminum frame suspended between stakes. The frame was constructed by J. Butler of Lakehead University Science Workshop. Each species touched by the pin was recorded once, regardless of the number of times that a species was touched in a single thrust of the pin. Only species falling under the frame were considered.

Once the pin came to rest lightly on the moss surface, the amount of pin remaining above the frame was measured in mm with a hand held tape and recorded (see figure M-2). This gave a reasonably accurate measurement of the microtopography along the transect because the stakes upon which the frame rested were of uniform elevation above the moss surface.

A total of 1110 point quadrats were taken at 10 cm intervals along the entire 111 metre length of the transect.

A further 700 point quadrats were taken at 2 cm intervals along the length of five *Sphagnum spp.* hummocks which were located along the transect. There was insufficient time to analyze the results of these measurements within the body of the thesis. Data was located in Appendix I.

e) Transects

One of the major goals of this study was to examine the vegetation changes along a gradient which ran from bog to fen. Whittaker (1967, 1973), Chapman (1976) and Kershaw (1973) recommend the transect as the ideal method of studying vegetation gradients. Seven transects were undertaken in this study. Each ran from muskeg to fen, three (A, B, G) from east muskeg to the fen centre, two from the north muskeg to the north end of the fen (C, D), and two from the west muskeg to the fen centre (E, F) (see figure M-1). Each transect was approximately 45 metres in length. A total of 100 samples were

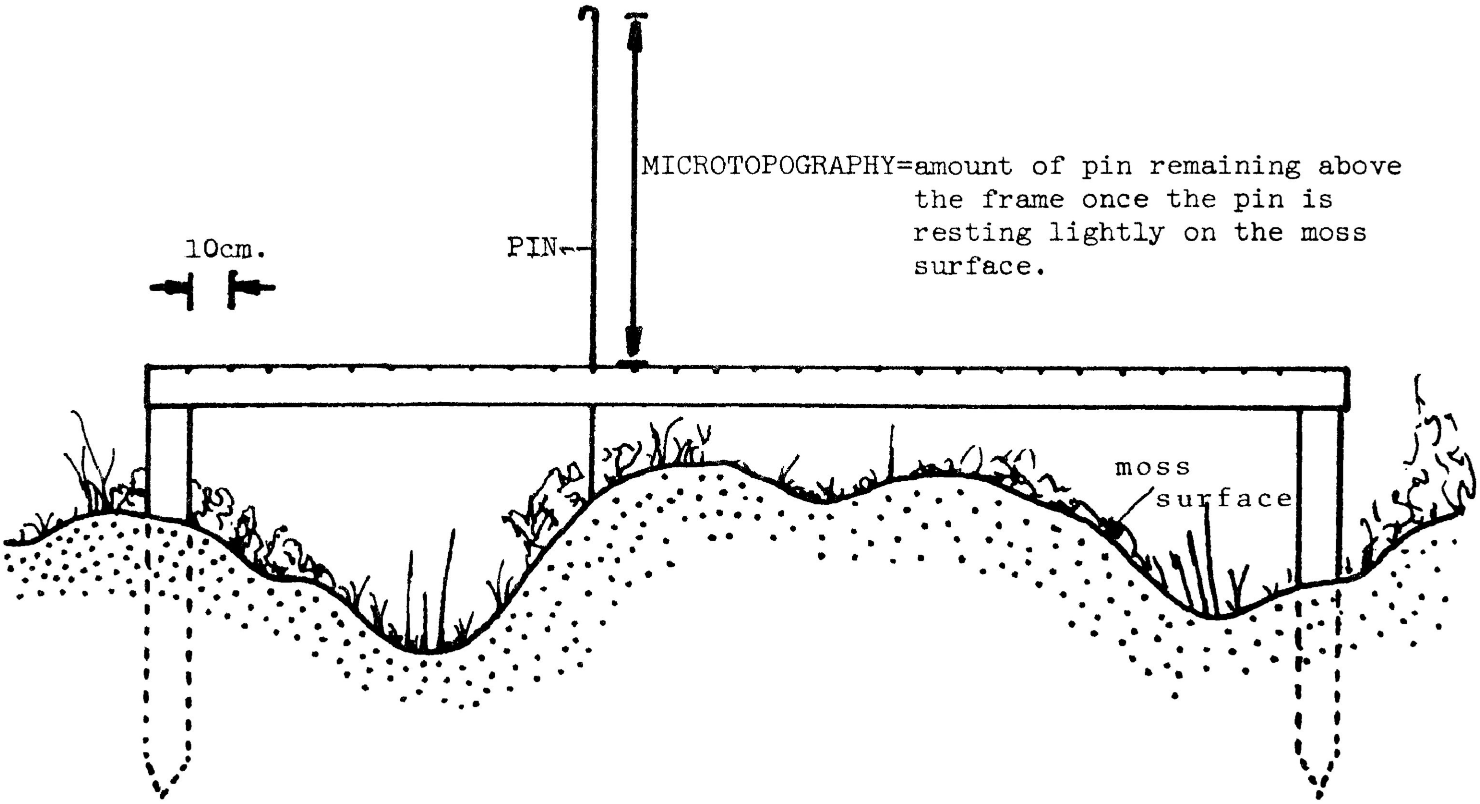


FIGURE M-2.Point quadrat frame design used in the study.

taken at 3 metre intervals along each transect with a 25 cm × 100 cm rectangular quadrat frame which was oriented parallel to the principal gradient of the vegetation (Chapman, 1976). Kershaw (1973) recommended systematic sampling along environmental gradients and **felt** that size of quadrat can be determined arbitrarily depending on the nature of the vegetation. The 25 cm × 100 cm quadrat used in this study was small enough to fit into the mosaic of *Sphagnum spp.* hummocks and wet hollows present without serious overlap; yet, large enough to adequately describe the nature of the vegetation.

Quadrats were labelled alphabetically according to transect and numbered continuously from 1 to 100. Within each quadrat, data was recorded on a plot sheet. All plant species present within the inside boundries of the quadrat frame, or falling within an imaginary rectangular box outlined by the frame, were identified, given a subjective Braun-Blanquet cover rating (Mueller-Dombois and Ellenberg, 1974) see table M-3 and a subjective Braun-Blanquet sociobility rating (Mueller-Dombois and Ellenberg, 1974) see table M-3. Unidentified species were collected, numbered, pressed and identified in the laboratory. The vegetation zone in which the quadrat was located was identified as either muskeg, dry transition, wet transition or fen. The physiogamy of the vegetation was briefly described and any comments about the site or individual species were

COVER CLASS	RANGE OF COVER(%)
+	Sparse or very sparce(small cover).
1	Plentiful,but of small cover value.
2	Very numerous or covering at least 5% of the area.
3	Any number of individuals covering 25%-50% of the area.
4	Any number of individuals covering 50%-75% of the area.
5	More than 75% of an area.

BRAUN-BLANQUET COVER SCALE(Mueller-Dombois and Ellenberg 1974)

1= Growing solitary.
2= Forming clumps of dense groups.
3= Forming small patches or cushions.
4= Growing in small colonies or forming larger carpets.
5= Growing in large, almost pure population stands.

BRAUN-BLANQUET SOCIABILITY SCALE

TABLE M-3.Braun-Blanquet cover scale(top) and Braun-Blanquet sociability scale(bottom). Measures of cover and sociability used in this study added to the quadrat data sheet. At the same time depth to the water table was measured from a spot of average elevation to the water table. Soil and water samples were taken and the peat given a von Post (1924) humification rating. See water and soil Methods for details.

Transects were undertaken on June 13 and 14, 1978 (A), June 18 (B), June 26 (C), June 27 (D), July 2 (E), July 4 (F) and July 20 (G). Comparison of species presence and cover between transects A and G show that there was little change in vegetational composition over the period from June 13 to July 20, 1978, only slight increases in cover of *Vaccinium oxycoccos* and *Carex chordorrhiza* were observed.

II Environmental factors

Introduction

Several environmental factors were monitored throughout the study area. Climatic factors measured were air and soil temperature and relative humidity. Water levels and peat mat levels were noted regularly (see figure M-4). Soils and ground water characteristics were measured along seven transects (A-G) and sampled from one hundred quadrats.

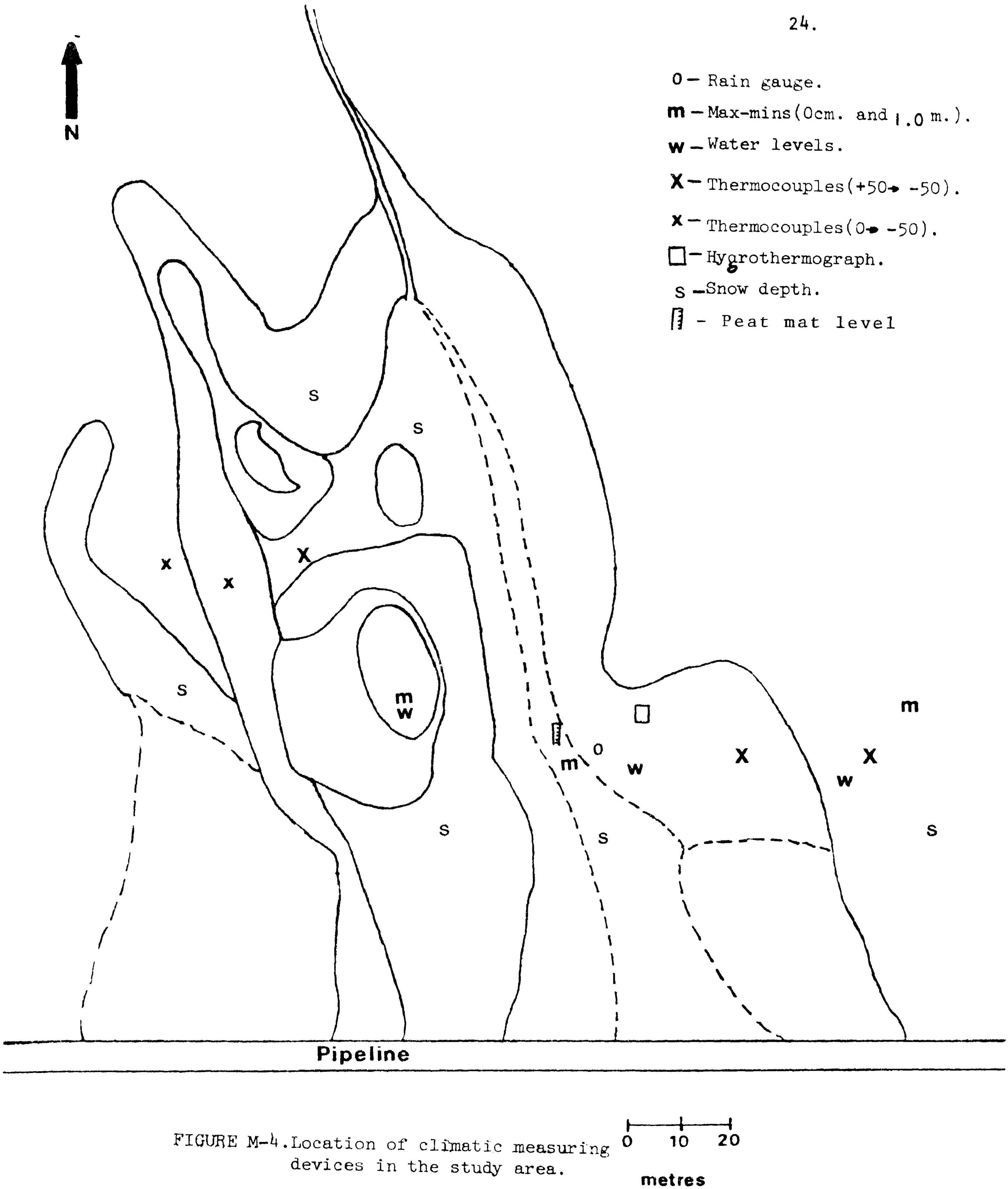


FIGURE M-4. Location of climatic measuring devices in the study area.

PLATE M-5. Hygrothermograph location in the study area.
Located in the eastern transition zone. Photograph provides view of the study area looking from east to west, to the fen and western muskeg.

a) Temperature

(i) Air temperature

Ambient

Air temperatures were recorded at three climate stations located with vegetation typical of muskeg, transition and fen. (See figure M-4)

Air temperature was recorded continuously from May 29, 1978 to November 15, 1978 by the bimetallic thermograph portion of a Casella thermohygrograph which was housed in a bird house shelter (Fraser 1961). Readings were terminated when cold temperatures resulted in frozen ink in the recording pen and a poor temperature record. The Birdhouse shelter was elevated 1.0 m. above the peat surface. It was elevated to avoid measurement of air temperatures near the peat surface which would not be representative of the ambient air temperature. The thermograph, which was calibrated monthly with a mercury in glass thermometer, was located in the transition zone east of the fen. See figure M-4; see plate M-5.

(ii) Surface and ambient temperature maxima and minima

Maximum and minimum air temperatures at the moss surface and 1.0 m above the moss surface were recorded weekly in sites representative of muskeg, transition and fen on the east side only. See figure M-4. Temperatures were recorded by Six's Maximum-Minimum thermometers which were attached to 40 mm × 60 mm boards facing north. The top of the upper thermometer was elevated one metre above the peat surface.

The lower thermometer rested on the surface. Readings were taken weekly, (usually Thursdays), between 10 AM and 1 PM in the following order: muskeg, transition and fen, within 15 minutes all readings were accomplished.

(iii) Soil temperature maxima and minima

Nine Six's maximum-minimum thermometers were located in three sites representative of muskeg, transition and fen on the east side of the study area. Thermometers were buried at three depths, 3 cm, 15 cm and 30 cm below the peat surface. Thermometers were set and buried horizontally on October 10, 1977. Their positions were marked with florescent flagging tape and left undisturbed until October 3, 1978. On this date they were retrieved and the temperature extremes for the twelve previous months were recorded. Thermometers buried in the muskeg site were lost because their location was inadequately marked. In the future very bright, obvious markers should be used to locate equipment in muskeg sites.

(iv) Soil, soil surface and groundwater temperatures

Temperatures above the soil surface, and within *Sphagnum spp.* hummocks, in sites representative of muskeg, transition and fen were measured using thermocouples of copper-constantan with soldered tips. Copper-constantan thermocouples are well suited to micro-climatological work because they are small, inexpensive, easily constructed, and reliable to 0.5°C (Platt and Griffith, 1964).

Thirty-four thermocouples were constructed in the laboratory. Copper-constantan thermocouple wire was stripped of insulation, the bare wires twisted and fused with acid-cored tin-lead solder. The fused tips were trimmed as close to the insulation as possible. An electromotive force (emf) is produced by the fused copper and constantan wires which is proportional to temperature (see Equation 1) (Platt and Griffith, 1964). Finally, the receptive surface was dipped in a thin coating of epoxy to prevent corrosion or damage. The opposite end of the thermocouple was soldered to two copper wire leads. The constantan-copper and copper-copper junctions were embedded in a block of paraffin together with a calibrated mercury-in-glass thermometer. These served as reference or "cold" junctions. The thermocouples were calibrated in the laboratory against boiling water (100°C) and an ice bath (0°C).

In order to facilitate rapid readings of temperature, colour coded thermocouples were connected to female Jones plugs, which were plugged into a socket connection switch box constructed by R. Wilson (see figure M-9) from Wilson (1970)). Thermocouples were securely taped to lengths of 6 mm dowling and embedded in a *Sphagnum spp.* hummock. Leads were laid carefully on the surface of the peat and wax embedded reference junctions were placed in shallow pits at the peat surface (see figure M-7 and M-8) in order to avoid major fluctuation in reference junction temperature over the period while measurements were taken.

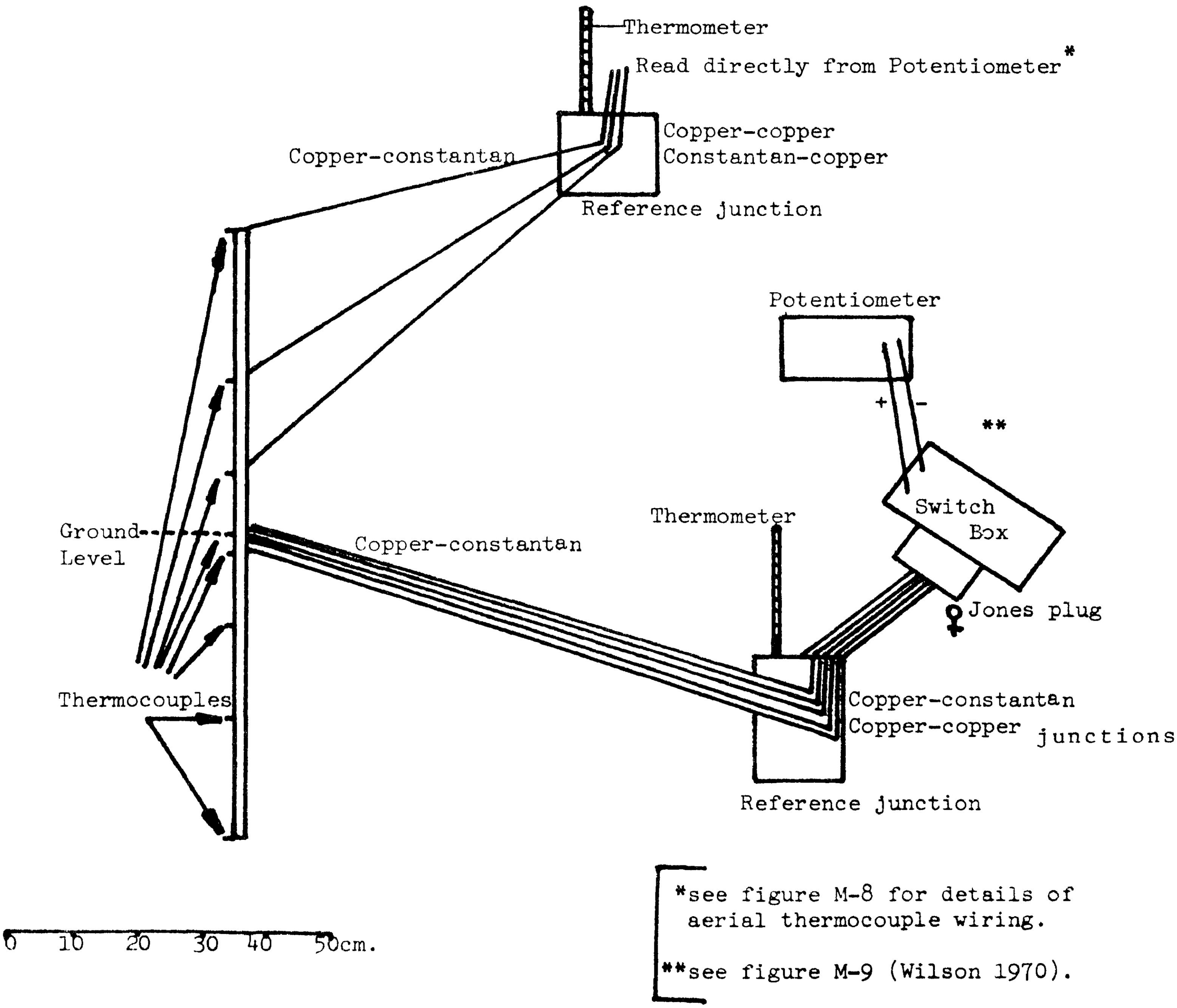


FIGURE M-7. Wiring details of a Thermocouple system in a *Sphagnum* spp. hummock.

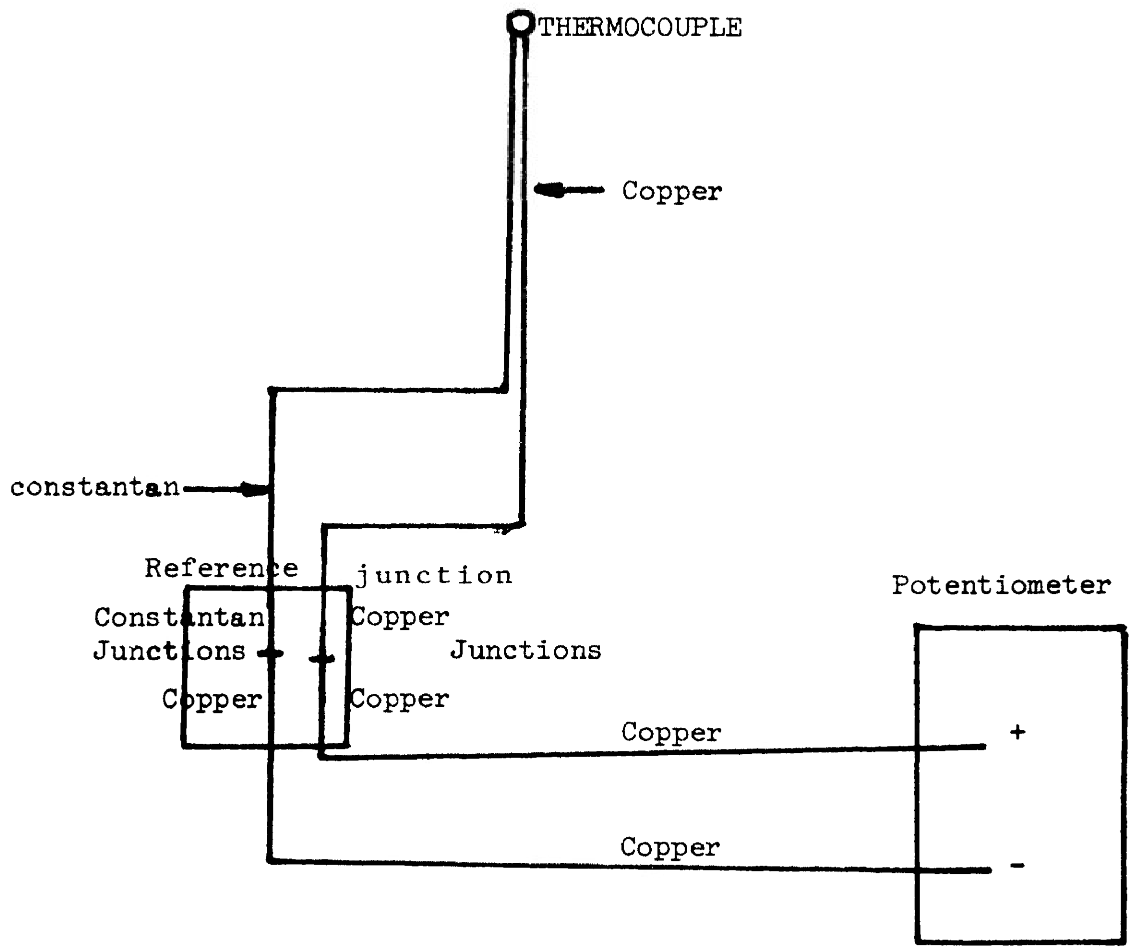


FIGURE M-8.Details of aerial Thermocouple wiring.

Temperatures were measured at the moss surface, 10 cm, 25 cm and 50 cm above the surface and 3 cm, 15 cm, 30 cm and 50 cm below the surface of three *Sphagnum spp.* hummocks in muskeg, transition and fen sites. (See figure M-7.) Temperatures at the surface and 3 cm, 15 cm, 30 cm and 50 cm below the surface were recorded from two additional hummocks in muskeg and transition sites to the west of the fen. (See figure M-4.)

Readings of electromotive force (emf) in millivolts were taken weekly from June 7, 1978 to November 14, 1978 with a Thermoelectric Digimite Potentiometer. The procedure for reading was to initially record the reference junction temperature in °C, then thermocouple readings in millivolts were taken from the lowermost thermocouple (-50 cm) through to the uppermost thermocouple (+50 cm). Once the complete sequence of thermocouples were read and recorded, the lowermost one was read again to see if there was any change in millivolt readings. No change was recorded throughout the period of study. The thermocouples at the surface, 10 cm, 25 cm and 50 cm above the surface were read again and if any change was observed, an average of the first and second readings was recorded. Finally, the reference junction temperature was recorded again. No differences were ever observed in reference junction temperatures probably because they were embedded in the peat and sheltered from solar radiation by vegetation.

The electromotive force (emf) produced between the fused wires of the thermocouple is directly proportional to temperature (see figure M10) Platt and Griffith (1964). Emf's were converted from millivolts to degrees Celcius in the manner outlined in equation 1. (Rinne 1976) Readings were considered accurate to 1.0°C.

Equation 1. $$E_t = E_{(t-tc)} + E_{tc}$$

where $E_{(t-tc)}$ = observed reading

E_{tc} = reference junction temperature in millivolts determined from Fig (emf vs °C)

E_t = corrected emf for the sensitive thermocouple and converted to °C from figure (emf vs °C)

Sample calculation

Reading from the potentiometer -1.04 mv with a reference junction temperature of 20°C.

$E_{(t-tc)} = -1.04$

$E_{tc} = 0.79$ (from fig (emf vs °C))

$\therefore E_t = -1.04 + 0.79 = -0.25$

temperature = -6.7°C (from fig (emf vs °C)) See Figure M-10.

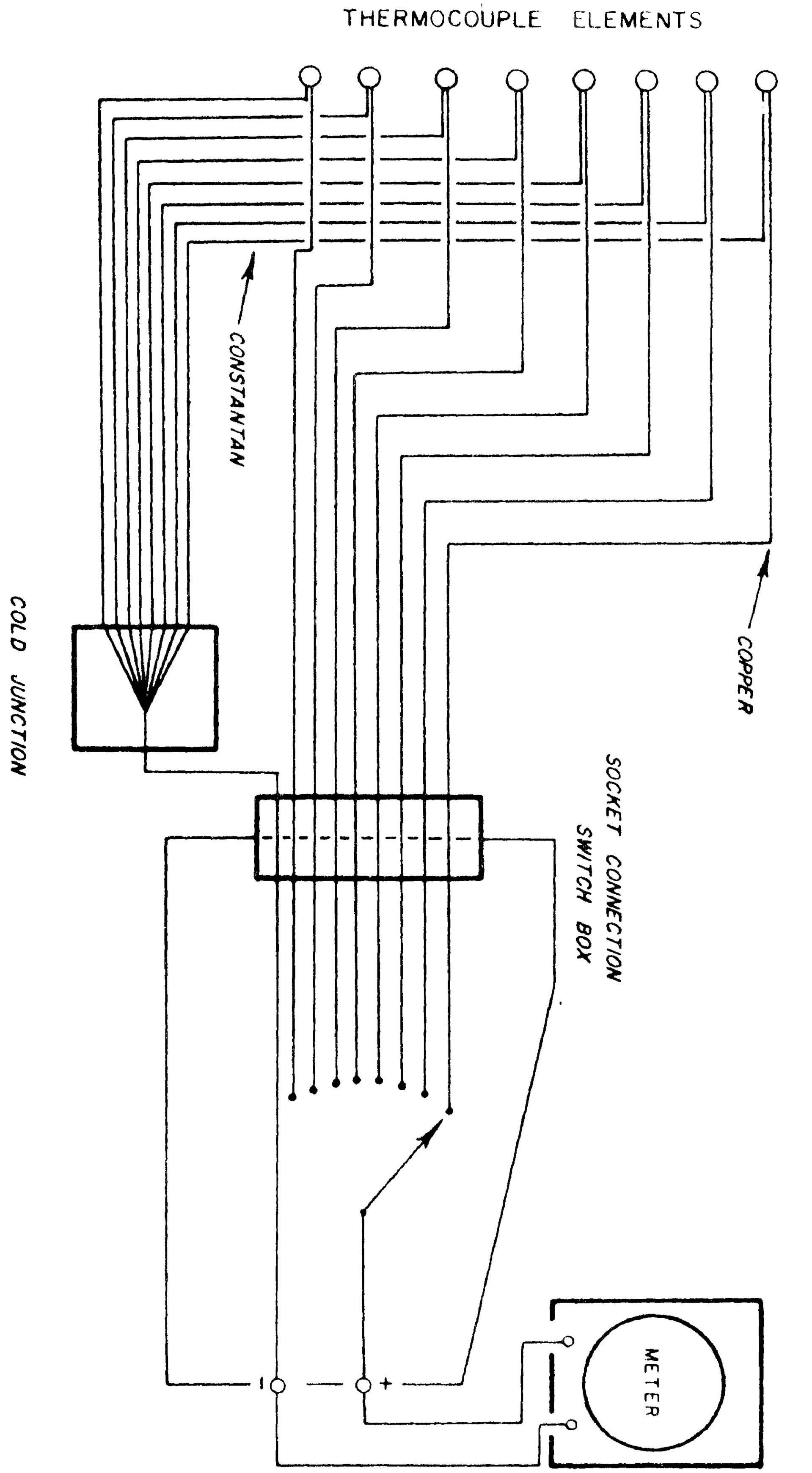


FIGURE M-9. Details of Jones plug wiring in subterranean Thermocouples (Wilson 1970).

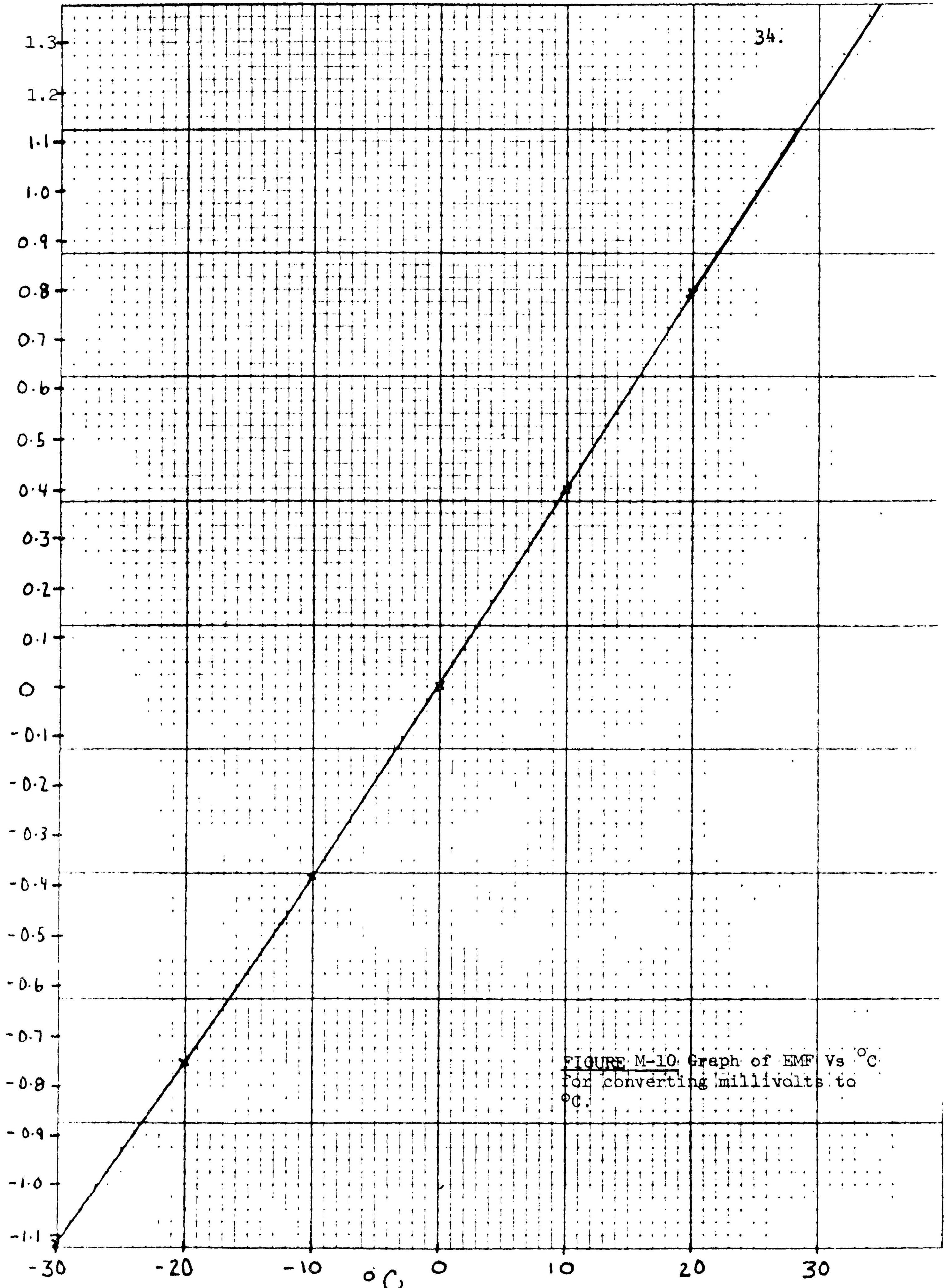


FIGURE M-10 Graph of EMF Vs °C for converting millivolts to °C.

b) Wind

A measurement of wind direction and intensity were made weekly while other climatic data were being collected. Subjective measurements of wind intensity were quantified using an empirical scale. See table M-11. Wind direction was determined by referring to north facing max-min thermometer standards.

Table M-11 Empirical scale devised for wind measurement

light	
breeze	2
moderate	3
brisk	4
strong	5

c) Precipitation and relative humidity

(i) Precipitation

Rainfall was recorded weekly from May 18, 1978 to November 14, 1978 at the climate station in the transition site. (See figure M-4.) It was measured with a single Cassella standard British rain gauge with a receiving area of 116.12 cm^2 and a rim diameter of 12.7 cm.

The rim of the gauge protruded 30.0 cm above the surface of the peat and was located in an area free from obstruction by large trees, shrubs or forbs. This avoided errors in measurement by splash back of rain from the ground into the gauge and interception of rainfall by vegetation (Platt and Griffith, 1964). Precipitation was also recorded from data taken by the meteorological station at the Thunder Bay Airport, 3 km from the study area at an elevation of 200 metres.

Snowfall was recorded biweekly from December 14, 1977 to April 10, 1978 by six metre sticks driven firmly 10 cm into the peat. Depth of snow against the metre stick was recorded by keeping the head at snow level and reading the level on the metre stick. Snow depth was recorded as the reading on the metre stick minus 10 cm.

Snow depths were recorded at six locations (see figure M-4) throughout the study area, the north and south ends of the fen, muskeg to the east and west of the fen, and in transition zones to the east and north of the fen. In the fen and muskeg, single readings were taken in areas free from large hummocks or hollows, at sites of average elevation. Transition sites had two measurements of snow depth, one metre stick was planted at the top of a hummock, the other in a hollow. Since transition zone topography was predominantly hummocks and hollows these measurements better assessed snow accumulation than a single measurement would.

(ii) Relative humidity

Relative humidity was recorded continuously from May 29, 1978 to November 15, 1978 by a standard Casella hair hygrograph which was part of the thermohygrograph housed in a bird house shelter in a transition site of the study area (see Air temperature section) (see figure M-4 and plate M-5). The hygrograph was calibrated monthly with an Assman psychrometer. Readings were accurate to 2%. Charts were changed and ink refilled weekly throughout the period of study.

Relative humidity was measured weekly from May 18, 1978 to October 10, 1978 by a standard sling psychrometer. Humidity readings are accurate to only 5% because sling psychrometers tend to over estimate relative humidity (Platt and Griffith, 1964). Readings were taken in muskeg, transition, and fen sites at water table reading sites.

Saturation deficits were not calculated in this study. Air moisture conditions were not measured precisely, per cent relative humidity was the only factor recorded - due to time and equipment limitations.

d) Water and soil level fluctuations

(i) Water table

The fluctuations in depth of the water table and movement of the peat mat were recorded from June 2, 1978 to November 14, 1978. Water table level measurements were taken with a tube and float device constructed by Mr. John Butler of the Lakehead University

Science Workshop from a design similar to that described by Green and Pearson (1968) (see figure M-12). Three tube and float devices were located throughout the study area in sites representative of muskeg, transition and fen, and in close proximity to climate stations located within each site. Readings were taken from tubes embedded in the peat up to the plexiglass apron (see figure M-12). The amount of aluminum rod protruding from the tube (see figure M-12) and held by the rubberized arms was recorded as the week's maximum reading, the arms were then released, the float was depressed slightly, and then allowed to rebound to the present water level, this was recorded as the level for that day. Readings were taken weekly in all three sites from June 23, 1978 to November 14, 1978. In the following order: muskeg, transition and fen, readings were completed in 15 minutes. Readings for the muskeg site were not possible before June 23, 1978 because the peat was frozen. Measurements were taken in transition and fen sites on June 2, 5, 7, 8, and 15th during a period of heavy rains and in all three sites on June 23, 26, 27 and 30th after more rain. These readings were used to obtain a detailed record of rainfall and water table fluctuations over a short period of time.

(ii) Peat mat fluctuation

Changes in the level of the peat mat were recorded at the same time as the water table levels. Measurement was accomplished by driving a 2.7 metre range pole past the peat and into the sands underlying the study area. Previous studies in the area

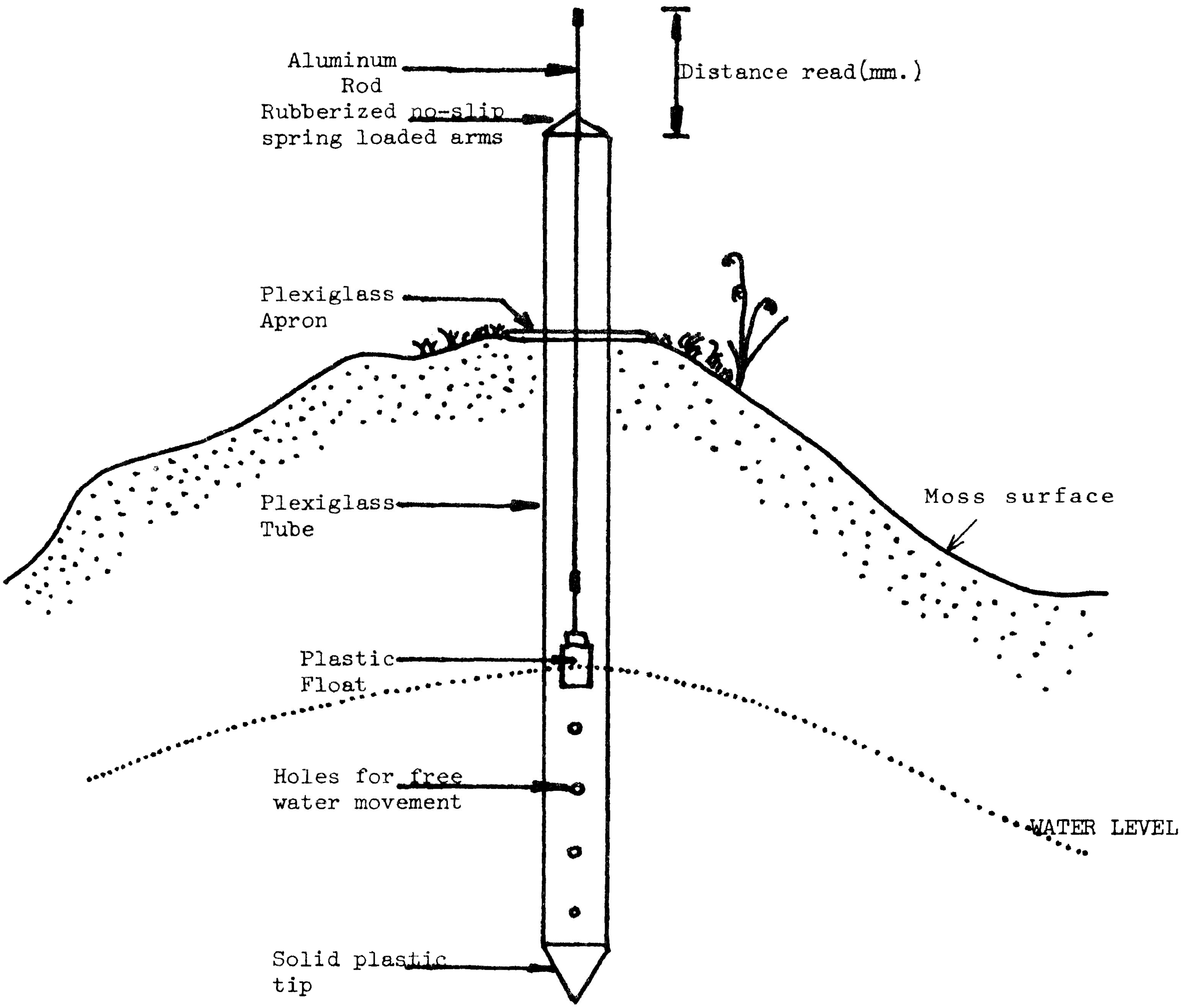


FIGURE M-12.Water table measuring device(to scale).

(Anrep, 1921) had shown the peat mat to be approximately 2 metres in depth. The range pole protruded 30.5 cm above the moss surface, therefore, it was assumed to be into the underlying sands. Readings were taken with a tape measure whose zero end rested lightly on the moss surface.

The range pole did not move because it was embedded in the parent material. However, the water tubes did move with fluctuations in the peat mat. Consequently, water level measurements between sites could not be compared directly, only the change in water level from reading to reading was compared between sites.

e) Soil and groundwater characteristics

e-i) Sampling technique

Twelve soil and groundwater characteristics: depth to water table, soil pH, loss on ignition, von Post (1924) humification, total C, H, N, ammonium, nitrate, water pH, conductance, and calcium concentration, were measured from 100 samples taken along a vegetation gradient which ran from muskeg to fen. Sampling of soil and water was achieved through transects running parallel to the vegetation gradient (see figure M-1). Soil samples were taken at 3 metre intervals from 25 cm × 100 cm rectangular quadrats (see Methods-Vegetation) along the transect. Samples were taken from a single spot which typified the vegetation enclosed by the quadrat. A 10 × 10 × 10 cm portion of soil was removed from beneath the living moss layer in the rooting zone of the dominant vegetation. Excess moisture was squeezed out and the sample placed in a labelled plastic bag sealed with a twist tie. A total of 100 soil samples were taken from seven transects.

Groundwater samples were taken from the same quadrats as the soil samples. Water samples were collected in 500 ml plastic bottles with screw-type lids, in close proximity to where the soil sample was taken, but, where no disturbance had occurred. Care was taken in quadrats which were less than 65% open water to sample the groundwater rather than surface water which had flowed into the hole remaining from the soil sample. In quadrats which were greater than 65% open water samples were collected from surface water.

For those analyses which were not done within four hours of sample collection, soil and groundwater samples were refrigerated and measured within 12 hours of collection.

e-2) Resampling

In order to check readings taken in June after a heavy rainfall a further set of samples were taken in November after a period of low rainfall. On November 9, 1978 five transects (A, C, D, E, F) were resampled. Soil and water samples were taken at 3 metre intervals along the transects. A total of 74 samples were collected and reanalyzed within four hours of collection. Water samples were then refrigerated and soil samples frozen.

e-3) Method of determining characteristics

(i) Depth to water table

The depth to the water table, from a point of average elevation within the quadrat, was determined by removing a column of peat 10 cm × 10 cm × 40 cm with a hand trowel. Fifteen minutes were allowed for the water level to equilibrate and then the depth to which the water had risen in the hole was measured with a hand held tape.

Depth to water table was measured in conjunction with soil sampling, peat removed from the hole was used for soils analysis.

(ii) Water pH

The pH of water samples was measured within 12 hours of collection by a Bechman pH meter with a glass measuring electrode and a calomel reference electrode. Before measurements were taken the meter was allowed to warm up for 30 minutes and standardized in 4.01 and 7.00 pH buffer solutions. Water samples were transferred to clean 150 ml glass beakers, and pH readings were taken once the meter's reading stabilized while swirling the water in the beaker (Brown, Skougstad and Fishman, 1970).

(iii) Calcium

Calcium concentration in water samples were determined by Dr. Griffith of the Lakehead University Chemistry Instrumentation Laboratory by atomic absorption spectrophotometry on the Perkin Elmer model 240 elemental analyzer. Portions of refrigerated water samples were analyzed without shaking and disturbing particular matter which might block the nebulizer. No attempt was made to standardize sample pH's. Dr. Griffith (per.comm.) Calcium concentration in ppm was accurate to 0.1 ppm in concentrations of less than 10 ppm and accurate to 0.01 ppm in concentrations greater than 10 ppm. (Brown, Skougstad and Fishman, 1970)

(iv) Water conductance

The ability of the water to carry an electric current was an indication, within rather wide limits, of the ionic strength of the solution. The conductance of a solution is the reciprocal of the resistance, which was measured in OHMS, of a column of solution 1 cm long and 1 cm^2 in cross section. In most water, conductance was so low that it had to be measured in micromhos (Brown, Skougstad and Fishman, 1970).

Conductance of water samples was measured within 12 hours of collection by a Yellow Springs Instrument SCT meter model 33 with two platinized electrodes in a plastic conductivity cell. The meter was standardized with a KCl solution when the readings were initiated. Readings were taken by immersing the conductivity cell in a clean 150 ml beaker containing the water sample. The beaker was swirled until the meter stabilized and the reading was recorded. Readings were considered accurate to ±1.0 micromhos at 20°C when dealing with values less than 1,000 micromhos (Brown, Stougstad and Fishman, 1970).

(v) Soil pH

Within twelve hours of collection pH of field moist soil samples were measured. One centimetre of peat was placed in a labelled glass beaker and enough distilled water was added to cover and moisten the soil into a thick slurry. The mixture was stirred vigorously and left standing for two hours to facilitate equilibrium of the peat-water mix. The mixture was stirred again and its pH measured directly with a glass measuring electrode and a calomel reference electrode on a Beckman pH meter. The meter was allowed to warm up for 30 minutes before it was standardized with pH 7.00 and pH 4.01 buffer solutions.

(vi) Total Carbon, hydrogen and nitrogen

Total C, H, N content of soil samples was determined by Mr. K. Pringnitz of the Lakehead University Science Instrumentation Laboratory using an atomic absorption spectrophotometer Perkin Elmer Model 240 Elemental Analyzer. Oven dried (102°C) samples were screened through 0.417 mm mesh to insure sample homogeneity because only 3-5 mg of sample were required for analysis.

Values for soil samples from each quadrat were expressed as percentages of carbon, hydrogen and nitrogen. Measurements were accurate to ±2.0% for carbon and hydrogen and ±0.3% for nitrogen (K. Pringnitz, pers. comm.).

Carbon to nitrogen ratios were calculated as follows.

Equation 2. $C \div N = X$

$X = C/N$ ratio (with $N = 1$)

(vii) Available Nitrogen

Determinations of the available nitrogen content (ammonium and nitrate) of soil samples from transects A and F were undertaken by the Ontario Soils Testing Laboratory, at the University of Guelph. Thirty samples from two transects, undertaken in the study area, were oven dried (102°C) and screened through 0.417 mm mesh. Samples were initially extracted with 1N KCL. Soil to extracting solution ratio was 1:10, with a thirty minute shaking period. Ammonium determination was by automated distillation from soil suspensions or coloured solutions (Hanawalt and Steckel, 1967). Nitrates were determined by modification of the automatic determination of nitrate in seawater method (Brewer and Riley, 1965). (E. F. Gagnon (pers.comm.)) Results were expressed as parts per million of ammonium and nitrates in each sample.

(viii) Loss on ignition

Determination of total organic matter in soil samples from quadrates 1-100 was accomplished through ignition of the soil in a Gallenkamp muffle furnace (Hesse 1971).

Screened (2.00 mm) peat samples were placed in weighed crucibles and oven dried (102°C) for 24 hours. Samples and crucibles were reweighed and placed in a Gallenkamp muffle furnace at 450°C for 4½ - 5 hours. Samples were cooled in a dessicator for 15 minutes and weighed.

Loss on ignition (L.I.) of the samples was determined in the following manner (Hesse 1971).

Equation 2a. $$\% \text{ L.I.} = \frac{\text{oven dried weight (g.)} - \text{burnt weight(g)}}{\text{oven dried weight(g.)} - \text{weight of crucible(g)}} \times 100$$

(ix) von Post humification of peat

The state of decomposition of the peat in soil samples taken from quadrats was determined using the von Post humification scale (von Post 1924). A handful of peat was collected and squeezed, the colour and clarity of the exudate, and the condition of the remaining pulp were noted and a von Post humification value was assigned. (See Table M-13.) Humification of the peat was determined for 100 quadrats in transects A-G.

von Post scale of decomposition: This field test involves squeezing a sample of the organic material contained within the closed hand, and observing the color of the solution that is expressed between the fingers, the nature of the fibers, and the proportion of the original sample that remains in the hand. Ten classes are defined as follows:

1 - Undecomposed: Plant structure unaltered. Yields only clear colourless water.

2 - Almost undecomposed: Plant structure distinct. Yields only clear water coloured light yellow-brown.

3 - Very weakly decomposed: Plant structure distinct. Yields distinctly turbid brown water; no peat substance passes between the fingers; residue not mushy.

4 - Weakly decomposed: Plant structure distinct. Yields strongly turbid water; no peat substance escapes between the fingers. Residue rather mushy.

5 - Moderately decomposed: plant structure still clear but becoming indistinct. Yields much turbid brown water; some peat escapes between the fingers; residue very mushy.

6 - Strongly decomposed: Plant structure somewhat indistinct but clearer in the squeezed residue than in the undisturbed peat. About a third of the peat escapes between the fingers; residue strongly mushy.

7 - Strongly decomposed: Plant structure indistinct but still recognisable. About half the peat escapes between the fingers.

8 - Very strongly decomposed: Plant structure very indistinct. About two-thirds of the peat escapes between the fingers; residue consists almost entirely of resistant remnants such as root fibers and wood.

9 - Almost completely decomposed: Plant structure almost unrecognisable. Almost all the peat escapes between the fingers.

10 - Completely decomposed: Plant structure unrecognisable. All the peat escapes between the fingers.

TABLE M-13. von Post scale of decomposition prepared by Dr. S. Zingle, Lakehead University, School of Forestry 1978.

f) Stratigraphy of the study area

The stratigraphy of the study area was examined through a series of six peat corings. Cores were taken in each major vegetation zone from the east side to the west side of the study area (see figure M-1). The depth and type of peat deposit underlying each major vegetation zone provided good information about the age, history of disturbance, previous vegetation and soils of the study area (Walker and Walker, 1961).

Cores were taken with a peat corer on October 9, 1978. This corer does not produce a continuous core, it takes cores in 75 cm sections. Consequently, stratigraphic profiles were determined by removing a core for every 75 cm and describing it in the field. Each core was examined for distinctive peat strata the strata were measured, mapped, given a von Post humification rating, dominant peat forming materials identified, and finally each strata was placed in a labelled plastic bag sealed with a twist tie.

pH of each strata was measured within four hours of collection (see Methods-Soil pH) and the remainder of the sample was frozen.

III Analysis of data

Introduction

Collected data was subjected to various analyses which included using the IBM 360/50 computer at Lakehead University, Thunder Bay, and the computer terminal located in the Canada Systems Group (Est.) Ltd., office in Sault Ste. Marie, Ontario.

Analysis was directed towards the interpretation of vegetation relationships through the performance of individual species, ordination of quadrats and grouping of related species. Environmental factors were correlated, grouped by quadrat's location and tested for significant differences between locations. Finally, vegetation-environment relationships were explored on ordinations of quadrats based upon vegetation data only, on ordinations based on environmental factors only, and on an ordination of species based upon quadrats and environmental data.

Using this approach it was hoped that the distribution of vegetation could be related to environmental factors and that the controlling factors could be identified.

a) Vegetation data

Once the collection of vegetation data from all eight transects was complete it was compiled as two data sets. The first set consisted of the results from 1,110 point quadrats undertaken along the level transect which bisected the study area from east to west. The second data set contained the vegetation present in 100 25 cm × 100 cm quadrats located along transects A-G.

(i) Point quadrats

Data from 1,110 point quadrats taken at 10 cm intervals was analyzed by calculator. The total number of hits for each species encountered along the transect was tallied over consecutive 3 metre sections of the transect. Presence is defined as "an individual or part of an individual rooted in the sample area" (Greig-Smith, 1964). Frequency was determined from the number of samples within a subjectively defined vegetation unit containing the species as a percentage of the total number of samples in that unit. Cover was defined by Greig-Smith (1964 p. 5) as the proportion of ground occupied by perpendicular projection onto it of the aerial parts of individuals of the species under consideration. Per cent cover of each species was determined by the following formula.

Equation 3.

$$\% \text{ cover of Species A} = \frac{\text{number of hits of species A in 3 metres}}{\text{total possible hits in 3 metres (30)}} \times 100$$

Per cent cover was calculated for 30 vascular and bryophyte species for 3 metre sections of the 37 metre transect and plotted as cover histograms along the entire length of the transect.

(ii) Bray and Curtis ordination

Vegetation data from transects A-G was transferred onto computer punch cards organized in the Trieste (Ĉeŝka pers. comm.) card format.

Quadrats 1-100 were ordinated using a program written by Mr. E. Wang of the University of New Brunswick for Lakehead University. This program accomplished a two dimensional ordination of quadrats, based upon floristic data only, using the methods of Bray and Curtis (1957).

Greig-Smith (1964), Whittaker (1967), and Kershaw (1973) recommended ordination as an effective method of analysis when studying an area whose vegetation may vary continuously in composition. It could be especially useful when dealing with vegetation along an environmental gradient.

Quadrats were ordinated in the following manner. Coefficients of similarity (C.S.) (Sorenson 1948) were calculated between all possible pairs of quadrats. From within the resultant matrix of C.S. values two plots were chosen to act as the X axis end points. Whittaker's (1973) method was employed to determine the two most dissimilar quadrats. Once the X-axis end points were determined the program was run again and quadrats were ordinated along a single X-axis. Y axis end points were chosen using a modified Whittaker's (1973) method, in which end points were subjectively chosen from quadrats which fell in the midregions of the X-axis, and showed a high degree of dissimilarity in location and vegetational composition. The program was run again and quadrats were ordinated between the Y axis end points.

Two dimensional ordination was accomplished by hand plotting of quadrats using the X and Y axis coordinates as generated by the Bray and Curtis ordination program.

The resultant ordination was examined for evidence of quadrat groups or continuums by plotting subjective vegetation category and location of individual quadrats. Braun-Blanquet cover values of the 30 most frequently occurring and ecologically restricted species were plotted at quadrat locations. Species distributions within the ordination were graphically illustrated.

(iii) Williams and Lambert Normal Analysis

Vegetation data from transects A-G was examined for statistically significant species groups which might have been present within the study area. This involved classification of the vegetation, a technique long employed by individuals studying the floristic composition of an area. This involves arranging quadrats into groups (Greig-Smith 1964) whose members have common species which set them apart from other groups of quadrats. Because no two quadrats were identical, classification was an arbitrary process. Species present in less than 10% of the quadrats were excluded from Normal Association analysis.

Classification of vegetation data was accomplished using a computer program written by Mr. E. Wang of the University of New Brunswick which employed Williams and Lambert Normal Association Analysis (Williams and Lambert 1959). This analysis delimited groups of quadrats on the basis of the highest summed chi-square value for each species as calculated by a series of 2 × 2 contingency tables which compared all possible pairs of species. The species which had the highest summed chi-square value was used as the criteria by which quadrats separated. This resulted in a hierarchical classification of quadrats based on the presence or absence of several species which exhibited high degrees of association, negative or positive, with other species present in the study area.

Due to the relative homogeneity of the vegetation, resulting from its continuous variation along the gradient from muskeg to fen, the chi-square cut off value for determining groups had to be lowered from 3.84 ($p \leq 0.01$) to 1.00 ($p \leq 0.25$) in order to get good group formation. This lowered the reliability of the Normal Association Analysis to 75%, but, enabled the program to run quite effectively and form groups, rather than rejecting the data set and forming no groups. All quadrat groups separated at chi-square levels less than 1.00 were included with their group, whose formation was at a chi-square value greater than one.

(iv) Principal components analysis based on vegetation only

In December 1978 there was an opportunity to further analyze data from the study area using a program written by Mr. C. Wehrhahn (University of Saskatchewan) and run by Mr. R. Sims (Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario). This involved use of Principal Components Analysis (P.C.A.) (Pearce, 1969) which produced ordinations of quadrats between as many component axes of variation as required. It utilized environmental data and vegetation data to produce axes. An explanation of how P.C.A. accomplishes ordination is given in the Vegetation-Environment Relationships section of the Methods of Analysis.

Vegetation data from transects B through F were used to produce a three dimensional ordination of quadrats. Detailed examination of the ordination showed that most of the information was contained in axes 1 and 2 and that this ordination was very similar to the ordination of quadrats resulting from Bray and Curtis ordination when inverted and rotated 90° to the left. Consequently, axis 3 was eliminated from further analyses.

P.C.A. ordinations were examined for evidence of quadrat groups or continuums. Subjective quadrat classification and location were plotted on the ordination and the ordination was scrutinized for group formations. The arrangement of quadrats was compared with Bray and Curtis ordination of quadrats.

b) Environmental data

Analysis of collected environmental data was directed towards determining if any significant differences existed between environmental factors and their location within the study area and the degree of association between factors.

(i) Climatic factors

Analysis of climatic factors (air temperature, soil temperature, relative humidity and precipitation) was accomplished by hand calculator.

(ii) *Soils and groundwater factors*

Analysis of soils and groundwater data was accomplished using the computer and by employing the Statistical Package for the Social Sciences (SPSS) program (Nie *et al.*, 1975).

Relationships between measured factors were determined through calculation of Pearson correlation coefficients, simple linear regression, and scattergrams plotted for each possible pair of factors.

Significance between single environmental factors grouped by subjective classification and location in relationship to the fen's centre was undertaken through one-way analysis of variance and Student's t-tests.

c) Vegetation-Environment Relationships

(i) *Bray and Curtis Ordination*

In order to determine if ordinated quadrats were sorted along environmental gradients, measured environmental values for each quadrat were plotted on the ordination and examined for indications of environmental gradients or discontinuities.

(ii) *Principal components analysis*

Vegetation-environment relationships were analyzed using Principal components analysis. Jeglum (1973) also employed P.C.A. to determine if any vegetation-environment relationships were present in the Candle Lake Wetlands in Saskatchewan.

P.C.A. produces ordinations of either quadrats or species using axes derived from both floristic and/or environmental data. A P.C.A. was perform on data from transects B-F. The first two component axes of variation were employed. These were derived from a matrix A of environmental measures × quadrats (or species × quadrats) which was used to generate a matrix R of environmentals × environmentals (or species) in pairs. The eigenvalues and corresponding eigenvectors of the matrix R were calculated and from these a component score was computed for each quadrat. These components were the new ordination axes, subject to the condition of mutual linear independence (Whittaker 1973).

The data was normalized rather than standardized. Walker and Wehrhahn (1971) recommended normalizing for situations when the researcher wanted to identify underlying gradients in the data.

Quadrats were plotted within the first two component axes. One ordination was based entirely upon environmental data, the other, an ordination of thirty-eight species, was based upon both floristic and environmental data.

The ordination based upon environmental factors only was examined for groups of quadrats or continuums. The subjective quadrat classification and the Normal group membership of a quadrat were plotted on separate copies of ordination sheets. Groups of similar quadrats were outlined.

An ordination of 30 species whose axes were based upon quadrat and environmental data was examined for species groups of ecological significance. Groups of species commonly associated in the field were enclosed by solid or dotted lines, depending upon the strength of their relationships.

The P.C.A. program, additionally, produced correlation coefficients for each species and environmental factor and the first, second and third component axes. It also calculated the total proportion of the variation in data which was accounted for by each axis. This data was examined to reveal which environmental factors were significantly correlated to the axes, and, which species were significantly correlated to the axes.

From the above, insight was gained regarding important environmental factors and individual species.

Thus, in the previously described manner the data from the study area was collected and analyzed. The following section deals with the results obtained by the outlined methods.

Results

Introduction

The first portion of the results section reports on the floral composition of the study area within William Bog, as derived from collections, observations, transects, and ordinations of the transect data.

The second section documents the results of measurements and subsequent analyses of climate, microclimate, soils and groundwater data collected from the study area.

The final portion of the results section deals with the relationships between vegetation and environmental factors through the use of ordinations constructed from floristic or environmental data.

Vegetation

a) List of species collected

Throughout the period of study vascular plants, mosses, and hepatic species present within the study area were routinely collected. Epiphytic species were not included in the collection. This is not a complete floral collection of William Bog.*

A total of 71 species of vascular plants, representing 24 families, were collected. Nomenclature is according to Gleason and Cronquist (1963).

---

*Other collections have been undertaken by Dr. P. Barclay-Estrup and Mr. C. Garton both of Lakehead University.

The Cyperaceae was the best represented family with twenty different species from four genera. Salicaceae was next, with nine species, and Ericaceae with six species. Collections, grouped by family, are listed in Table R-1. Family arrangement is according to Dalla, Torre and Harms (1958). Thirty-seven mosses were collected representing twelve families. The Sphagna were most common with twelve species.

Of the remaining twenty-four moss species, two had interesting habitat preferences. *Leptobryum pyriforme* (Hedw.) Wils was found growing on the body of a dead rodent and *Splachnum ampullaceum* Hedw., a coprophyllous species, was collected on moose pellets.

Thirteen species of hepatics representing seven families were collected.

Nomenclature of the mosses is according to Crum (1976) and nomenclature of the hepatics is according to Stotler and Crandall-Stotler (1977).

Although lichens were common epiphytes in the study area, no ground lichens were collected from the surface where collections were concentrated.

Table R-1

List of Vascular Species Collected

Equisetaceae

Equisetum fluviatile L.

Pinaceae

Picea mariana (Mill) B.S.P.
Larix laricina (Du Roi) K. Koch

Cupressaceae

Thuja occidentalis L.

Juncaginaceae

Triglochin palustre L.
Triglochin maritima L.

Graminaceae

Calamagrostis canadensis (Michx.) Beauv.
Muhlenbergia glomerata (Willd.) Trin.
Phragmites communis Trin.

Cyperaceae

Carex aquatilis Wahlenb. subs. *aquatilis*
Carex bebbii Olney.
Carex canescens L.
Carex chordorrhiza L.f.
Carex disperma Dewey.
Carex exilis Dewey.
Carex garberi Fern. = Carex aurea Nutt.
Carex gynocrates Wormsk.
Carex lasiocarpa subsp. americana Fern.
Carex lasiocarpa Ehrh.
Carex limosa L.
Carex livida (Wahlenb.) Willd.
Carex tenuiflora Wahlenb.
Carex trisperma Dewey
Dulichium arundinaceum (L.) Britt.
Eriophorum angustifolium Honckeny
Eriophorum spissum Fern.
Eriophorum viridi-carinatum (Engelm.) Fern.
Scirpus caespitosus L.
Scirpus cyperinus (L.) Kunth
Scirpus hudsonianus (Michx.) Fern

Araceae

Calla palustris L.

Juncaceae

Juncus tenuis Willd.

Lilliaceae

Smilacina trifolia (L.) Desf.
Tofieldia glutinosa (Michx.) Pers.

Orchidaceae

Arethusa bulbosa L.
Habenaria hyperborea (L.) R. Br.
Habenaria nivea (Nutt.) Spreng.
Pogonia ophioglossoides (L.) Ker.

Salicaceae

Salix amygdaloides Andersson
Salix candida Flugge
Salix maccalliana Rowlee
Salix monticola Bebb.
Salix pedicellaris Pursh var *hypoglauca* Fernald
Salix planifolia Pursh
Salix pyrifolia Andersson
Salix rigida Muhl.
Salix serissima (Bailey) Fern.

Myricaceae

Myrica gale L.

Betulaceae

Alnus rugosa (Du Roi) Spreng.
Betula pumila L.
Populus balsamifera L.

Santalaceae

Comandra livida Richards

Sarraceniaceae

Sarracenia purpurea L.

Droseraceae

Drosera rotundifolia L.
Drosera anglica Huds.

Saxifragaceae

Parnassia palustris L.

Rosaceae

Fragaria virginiana Duchesne
Potentilla fruticosa L.
Potentilla palustris (L.) Scop
Rubus acaulis Michx.

Ericaceae

Andromeda glaucophylla Link
Chamaedaphne calyculata (L.) Moench
Kalmia polifolia Wang
Ledum groenlandicum Oeder.
Vaccinium oxycoccos L.
Vaccinium vitis-idaea L.

Lentibulariaceae

Utricularia radiata Small

Caprifoliaceae

Lonicera villosa (Michx.) R. & S.

Campanulaceae

Lobelia kalmii L.

Menyanthaceae

Menyanthes trifoliata L.

Asteraceae

Aster laurentianus Fern.
Solidago uliginosa Nutt.

Table R-2

<u>List of Mosses Collected</u>

Sphagnaceae

Sphagnum magellanicum Brid.

Sphagnum squarrosum Crome.
Sphagnum teres (Schimp) Hartm.

Sphagnum recurvum var tenue Klinggr.
Sphagnum recurvum var brevefolium (Braithw) Warnst.

Sphagnum fimbriatum Hook. & Wils.
Sphagnum russowii Warnst.
Sphagnum fuscum (Schimp.) Klinggr.
Sphagnum capillifolium (Ehrh.) Hedw.
Sphagnum capillifolium var tenellum (Schimp.) Crum
Sphagnum balticum (Russ) Jens.

Sphagnum subsecundum Nees. ex strum.

Ditrichaceae

Ceratodon purpureus (Hedw.) Brid

Dicranaceae

Dicranum polysetum Sw.
Dicranum undulatum (D. bergeri Bland)

Splachnaceae

Splachnum ampullaceum Hedw.

Bryaceae

Leptobryum pyriforme (Hedw.) Wils
Pohlia nutans (Hedw.) Lindb.
Pohlia wahlenbergii (W & M) Andr.

Mniaceae

Rhizomnium appalachianum Kop.
Rhizomnium pseudopunctatum (Bruch. & Schimp.) Kop.

Aulacomniaceae

Aulacomnium palustre (W. & M.) Schw.

Amblystegiaceae

Calliergon giganteum (Hedw.) Limpr.
Calliergon stramineum (Brid.) Kindb.
Campylium stellatum (Hedw.) C. Jens.
Drepanocladus exannulatus (B. S. G.) Warnst.
Drepanocladus revolvens (Sw.) Warnst.
Drepanocladus uncinatus (Hedw.) Warnst.

Brachytheciaceae

Pleurozium schreberi (Brid.) Mitt.
Tomenthypnum nitens (Hedw.) Loeske.
Tomenthypnum nitens var falcifolium (Ren ex Nich.) Podp.

Hypnaceae

Ptilium crista-castrensis (Hedw.) De Not.

Hylocomiaceae

Hylocomnium splendens (Hedw.) B.S.G.

Polytrichaceae

Polytrichum juniperinum var affine (Funck) Brid.
Polytrichum strictum Brid.

Table R-3

List of Hepatics Collected

Ptilidiaceae (Blepharostomaceae)	
	Ptilidium pulcherrimum (Web.) Hampe.
Lepidoziaceae	
	Lepidozia reptans (L.) Dum.
Calypogeiaceae	
	Calypogeia neesiana (Mass. & Carest.) K. Mull.
Cephaloziaceae	
	Cephalozia bicuspidata (L.) Dum.
	Cephalozia connivens (Dicks) Lindb.
	Cephalozia loitlesbergeri Schiffn.
	Cephalozia lunulifolia (Dum.) Dum.
	Odontoschisma denudatum (Nees) Dum.
	Odontoschisma elongatum (Lindb.) Evs.
	Cladopodiella fluitans (Nees) Joerg.
Scapaniaceae	
	Scapania paludicola Loeske & K. Mull
Harpanthaceae (Lophocoleaceae)	
	Geocalyx graveolens (Schrad.) Nees.
Plagiocliaceae	
	Mylia anomala (Hoak) Sf. Gray

b) Subjective classification of the vegetation of the study area

Within the study area there were several obvious units of vegetation which differed in physiogamy and species composition. An effort was made to map the major units while in the field and to refine the units' boundries using aerial photographs. The resultant map of vegetation units (figure R-4) p. 73 was entirely subjective. It is a representation of the vegetation patterns present in the study area. Units are labelled according to their physiognomy and dominant vegetation. Figure R-4 is primarily for orientation within the study area and to provide a preliminary classification.

ZONE 1.

Picea mariana muskeg forest dominated the area east of the fen (zone 1). It was fairly dry and consisted of a mosaic of dense trees and more open treed shrubby patches with *Chamaedaphne calyculata* in open sites and *Ledum groenlandicum* in shaded sites. The moss layer contained a variety of aged *Sphagnum spp.* hummocks often capped by *Pleurozium schreberi*, a few *Hylocomnium splendens* and frequently interconnected by small *Dicranum polysetum* hummocks.

ZONE 2.

Next to the pipeline, in the extreme south-east corner of the study area, there was a region of wet transition which started abruptly from the eastern muskeg (zone 2). This small site was dominated by large *Sphagnum magellanicum* hummocks topped with a dense growth of *Andromeda glaucophylla* shrubs. Hollows are deep pools that often contained *Phragmites communis*. This species was often found growing from the centres of *S. magellanicum* hummocks in zone 2.

ZONE 3.

North of the wet transition (zone 2) and directly west of the muskeg /there was a distinct dry transition zone dominated by *Chamaedaphne calyculata*, *Kalmia polifolia* and *Vaccinium oxycoccos*. This zone was dotted by clumps of *Picea mariana* less than 2 metres in height. The moss layer consisted of well developed *Sphagnum fuscum* hummocks whose tops were covered with *Vaccinium oxycoccos*, *Carex chordorrhiza* and *Polytrichum juniperinum var affine*. Hollows between the hummocks were either shallow pools or loose tufts of *Sphagnum magellanicum* or

Sphagnum recurvum or small hummocks of the less common Sphagna, particularly the varieties of *S. recurvum*, *S. tenue* and *S. brevifolium*.

ZONE 4.

The dry eastern transition graded into a wet transition zone immediately to the west. This zone (zone 4) was dominated by large, loose *Sphagnum magellanicum* hummocks, wet hollows, and a mosaic of drainage tracks. This area lacked a distinct shrub layer. Hummocks were topped by *Sarracenia purpurea*, *Drosera rotundifolia* and *Carex limosa*. Hollows frequently supported growth of *Potentilla palustris* and *Menyanthes trifoliata*. *Equisetum fluviatile* was very common, but does not achieve high cover. The *Carex spp.* flora was somewhat restricted.

ZONE 5.

To the west is zone 5, a fen which was predominantly narrow leaved *Carex* species (*Carex exilis*, *Carex gynocrates* dominant) forming the matrix in which large, well developed, moist *Sphagnum magellanicum* hummock occurred periodically. The larger of these hummocks were topped by the same species as zone 4 hummocks. Hollows were also similar to zone 4, but sustained many species of *Carex* and *Utricularia radiata*. It is in this zone that most orchid species were collected and insectivorous plants were most frequently encountered.

ZONE 6.

Zone 6 was one of the wettest parts of the fen. This was a quaking mat of narrow leaved *Carex* species similar to those in zone 5. There were no hummocks or hollows, mosses common to this site were *Drepanocladus exannulatus*, *Scorpidium scorpioides Campylium stellatum*, *Aulacomnium palustre*, *Calliergon giganteum*, *Sphagnum subsecundum*, and *Sphagnum teres*. These are the brown mosses (Ahti and Hepburn, 1967). The orchid *Arethusa bulbosa* was particularly common in this site. This site was usually under at least 25 cm of water.

ZONES 7 and 8.

A floating mat of *Carex spp.* peat was present in the fen's centre, it consisted of a ring of *Phragmites communis* (zone 7) surrounding a patch of *Eriophorum spissum* (zone 8). This floating mat complex was also found in the northwest corner of the fen. Peat was well decomposed, water was usually over 50 cm in depth. These zones had little other vegetation within them except for an occasional member of the brown moss group, *Utricularia radiata*, and numerous individuals of *Calla palustris*.

ZONE 9.

This was a narrow band of very shrubby vegetation immediately west of the fen. Its westernmost regions were dominated by *Salix* species (including *Salix pedicellaris*, *S. pyrifolia*, *S. candida*, *S. serissima*, *S. maccalliana*) greater than 1.5 m in height. Towards the fen *Myrica gale* was dominant and *Lonicera villosa* was often present. The understorey was largely thick tussocks of *Scirpus caespitosus*, *Scirpus hudsonianus* and mixed *Carex* species. (*Carex livida*, *C. lasiocarpa* and *Eriophorum viridi-carinatum*). Sphagna were rare, when present they existed as small hummocks between *Scirpus spp.* tussocks. Species included *Sphagnum balticum*, *S. fimbriatum* and *S. russowii*. a few vasculars such as *Potentilla fruticosa* and *Rubus acaulis* were present.

ZONE 10.

The shrubby wet transition (zone 9) graded into an open wet transition to the north and northeast. This was an open site, consisting largely of *Sphagnum magellanicum* hummocks, shallow hollows, and widely spaced *Larix laricina*. It was a broad, wet transition zone with several drainage tracks running through it, usually in a south-west direction. Its herb layer was restricted to the occasional hummock top sustaining *Sarracenia purpurea*, *Drosera rotundifolia*, *Eriophorum angustifolium* and *Carex limosa*. Hollows were dominated by *Equisetum fluviatile*. Zone 10 was separated from zone 3 by a narrow stream with perceptible flow, bounded by a well developed *Carex lasiocarpa* zone on either side. This stream emptied into zone 5.

ZONE 11.

Immediately north of zone 10 is zone 11. This was a well developed stand of *Picea mariana* and *Larix laricina* (ratio approximately 3 to 1) growing on a peaty substrate dominated by broad leaved *Carex* species (*Carex aquatilis*, *C. pebbii*, *C. tenuifolia*, *C. lasiocarpa*) and *Carex disperma* and *C. limosa*. Sphagna were rare in the moss layer, although old erroded hummocks were visible between the tangle of tree roots, open water and *Carex* species.

ZONE 12.

Finally, zone 12 supported a thick growth of *Picea mariana*, *Thuja occidentalis* and *Larix laricina* forest which occupied the extreme western reaches of the study area. Zone 12 ended abruptly with zone 9 and graded into zone 11. Its understorey was dominated by *Calamagrostis canadensis* in sites where light could penetrate. The site has a large hepatic flora tucked in beneath the conifers. Species common to this site were *Mylia anomala*, *Cephalozia loitlesbergii* and *Odontoschisma elongatum*.

Legend of vegetation zones illustrated in Figure R-4

1. Picea mariana - Muskeg forest EAST
2. Andromeda glaucophylla - Sphagnum magellanicum wet Transition zone EAST
3. Chamaedaphne calyculata - Sphagnum fuscum Dry transition EAST
4. Equisetum fluviatile - Sphagnum magellanicum wet Transition zone EAST
5. Equisetum fluviatile - narrow leaved Carex hummocky Fen EAST and NORTH
6. Equisetum fluviatile - narrow leaved Carex wet Fen CENTRE
7. Phragmites communis floating fen CENTRE and NORTH
8. Eriophorum spissum floating Fen CENTRE and NORTH
9. Myrica gale - Salix spp.- Scirpus wet Transition WEST
10. Larix laricina - Sphagnum magellanicum wet Transition NORTH
11. Picea mariana - Larix laricina - broad leaved Carex Muskeg NORTH and WEST
12. Picea mariana - Thuja occidentalis - Calamagrostis canadensis Muskeg WEST

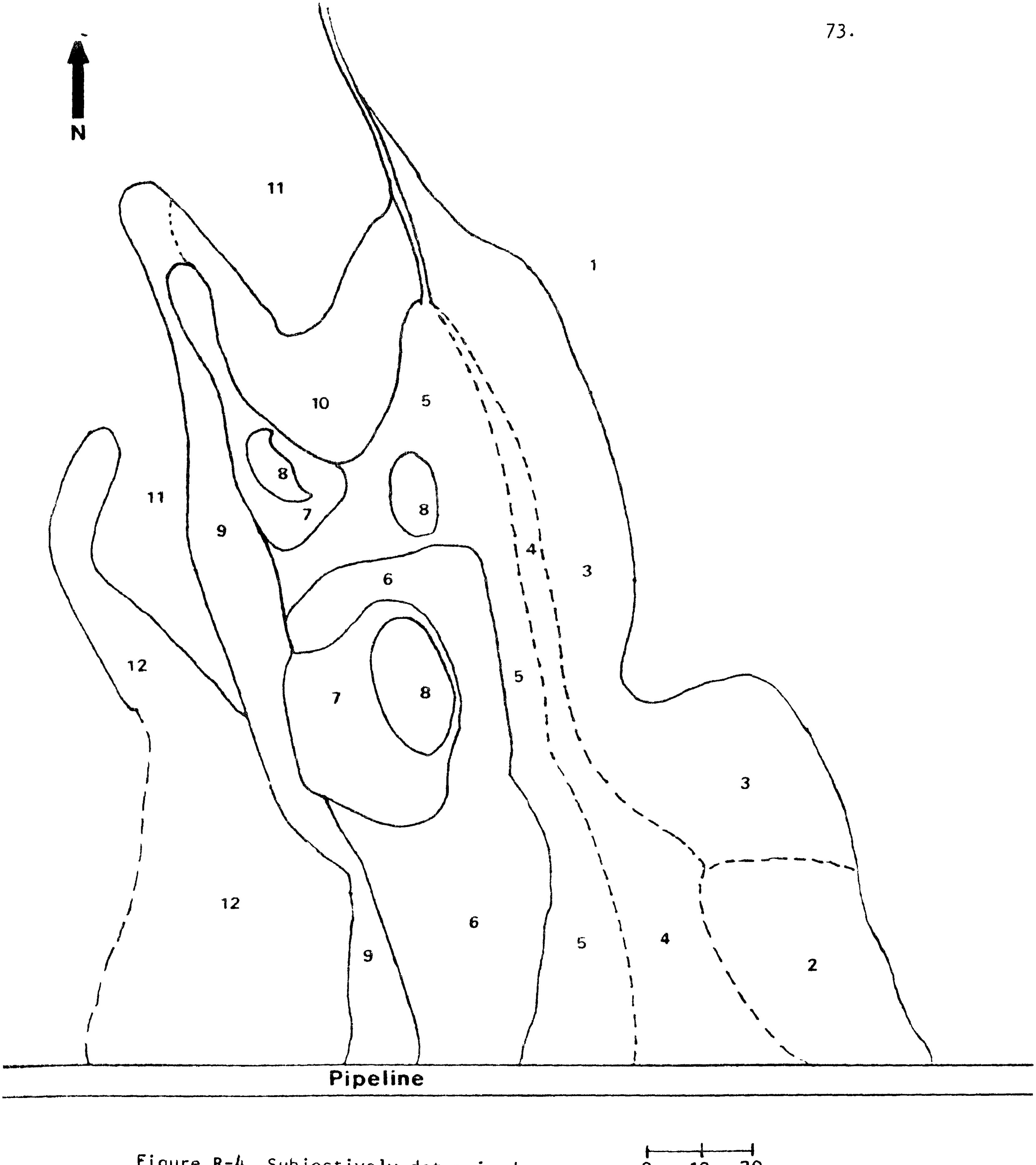


Figure R-4 Subjectively determined vegetation zones in the study area occupying a central region of William Bog, Thunder Bay.

c) Ages of trees in subjectively defined vegetation zones

The largest and tallest tree present within subjectively determined muskeg, transition and fen sites east and west of the fen's centre were felled and their ages determined from disks removed at moss level.

Table R-5 outlines the results of ring counts. The largest trees in muskeg sites were *Picea mariana*. The western muskeg tree was slightly taller and had a greater D.B.H. although younger than the eastern muskeg tree (100 years west, 106 east). *Larix laricina* dominated the transition zone, trees were also much younger in transition zones than the *Picea mariana* on muskeg sites.

The eastern transition tree was slightly older and larger than its western counterpart (62 years east, 54 years west). *Larix laricina* was also common in the fen. An average specimen was 12 years old, 2 metres high with a diameter of 2.5 cm at breast height.

Table R-5 Ages of largest trees in subjectively determined vegetation zone

Zone		Species	Age (moss level)	Disk Diameter	DBH	Height
Eastern muskeg	(1)	*Picea mariana*	106 years	12.75 cm	11.4 cm	6.5 m
Western muskeg	(12)	*Picea mariana*	100 years	15.40 cm	14.2 cm	8.0 m
Eastern transition	(3)	*Larix laricina*	62 years	10.8 cm	7.8 cm	3.5 m
Western transition	(9)	*Larix laricina*	54 years	10.8 cm	8.5 cm	3.3 m
Fen	(5)	*Larix laricina*	12 years	3.1 cm	2.5 cm	2.0 m

d) Species cover over an east-west transect of the study area

Objective measurements of species cover, along a single leveled transect bisecting the study area from east to west, were undertaken using point quadrats. (See Methods section I.)

Figures R-7, R-8, R-10 and R-11 illustrate the per cent cover of vascular and bryophyte species in 3 metre segments of the transect. Tables R-6 and R-9 document the percent frequency of species encountered along the transect in each major subjectively determined vegetation zone.

The vascular species which were common to all vegetation zones are *Chamaedaphne calyculata, Vaccinium oxycoccos, Equisetum fluviatile, Andromeda glaucophylla*, and *Carex limosa*. Of these species, *Equisetum fluviatile* achieved the highest cover values in east muskeg, east dry transition, fen and western wet transition vegetation types. It was least often encountered in the western muskeg. This species appeared to have a fairly broad ecological amplitude. *Vaccinium oxycoccos* also appeared to have a broad ecological amplitude, it was least common in the eastern muskeg.

continued on page 84.

Table R-6 % Frequency of vascular species in subjectively defined units along E-W transect. Data compiled over consecutive three metre sections of the level transect.

Species	East Muskeg	E. Dry Trans.	E. Wet Trans.	Fen	W. Wet Trans.	W. Muskeg
Chamaedaphne Calyculata	33.3%	100 %	100 %	46.2%	100 %	66.6%
Vaccinium oxycoccos	66.6	100	100	76.9	100	100
Equisetum fluviatile	100	100	66.6	100	100	33.3
Andromeda glaucophylla	33.3	42.8	100	69.2	75	33.3
Kalmia polifolia	33.3	71.4	33.3	0	0	0
Carex limosa	66.6	85.7	100	100	100	100
Smilacina trifolia	66.6	14.3	0	7.6	0	33.3
Picea mariana	100	0	0	0	0	33.3
Ledum groenlandicum	100	57.1	0	0	0	66.6
Carex trisperma	100	28.5	0	0	0	0
Eriophorum viridi-carinatum	33.3	100	100	23.0	0	0
Carex chordorrhiza		71.4	33.3	0	37.5	66.6
Drosera rotundifolia		42.9	33.3	15.4	62.5	66.6

Table R-6 continued

Species	East Muskeg	E. Dry Trans.	E. Wet Trans.	Fen	W. Wet Trans.	W. Muskeg
Eriophorum angustifolium	0	0	66.6	30.7	12.5	0
Carex exilis	0	0	100	76.9	37.5	0
Menyanthes trifoliata	0	28.5	100	76.9	0	0
Scirpus caespitosus	0	0	33.3	30.7	0	0
Utricularia radiata	0	0	0	61.5	0	0
Eriophorum spissum	0	0	0	30.7	0	0
Carex lasiocarpa	0	0	0	23.0	25.0	66.6
Myrica gale	0	0	0	0	75	100

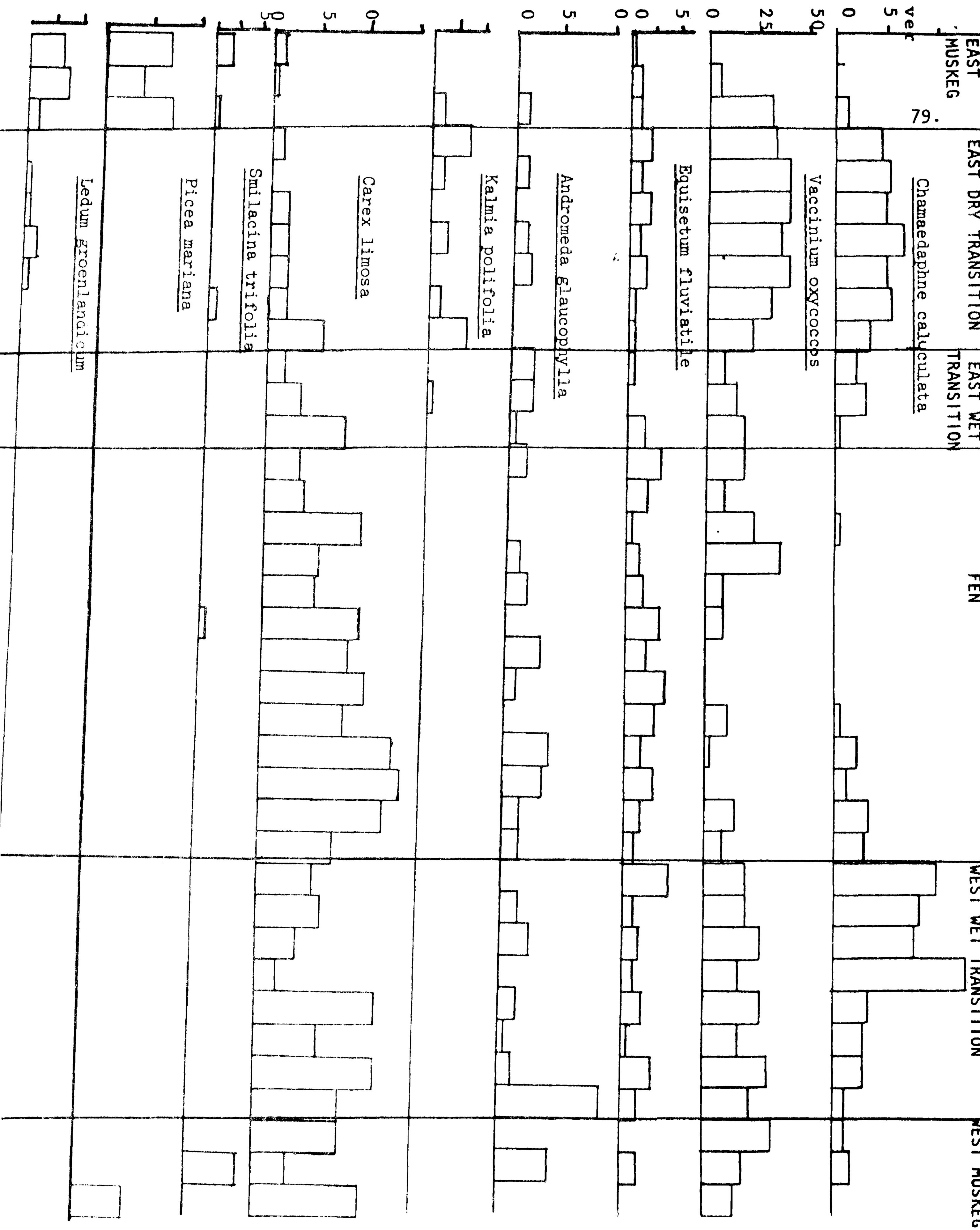


Figure R-7 Percent cover of vascular species determined by point quadrats totalled over consecutive 3 m sections of a level E-W transect

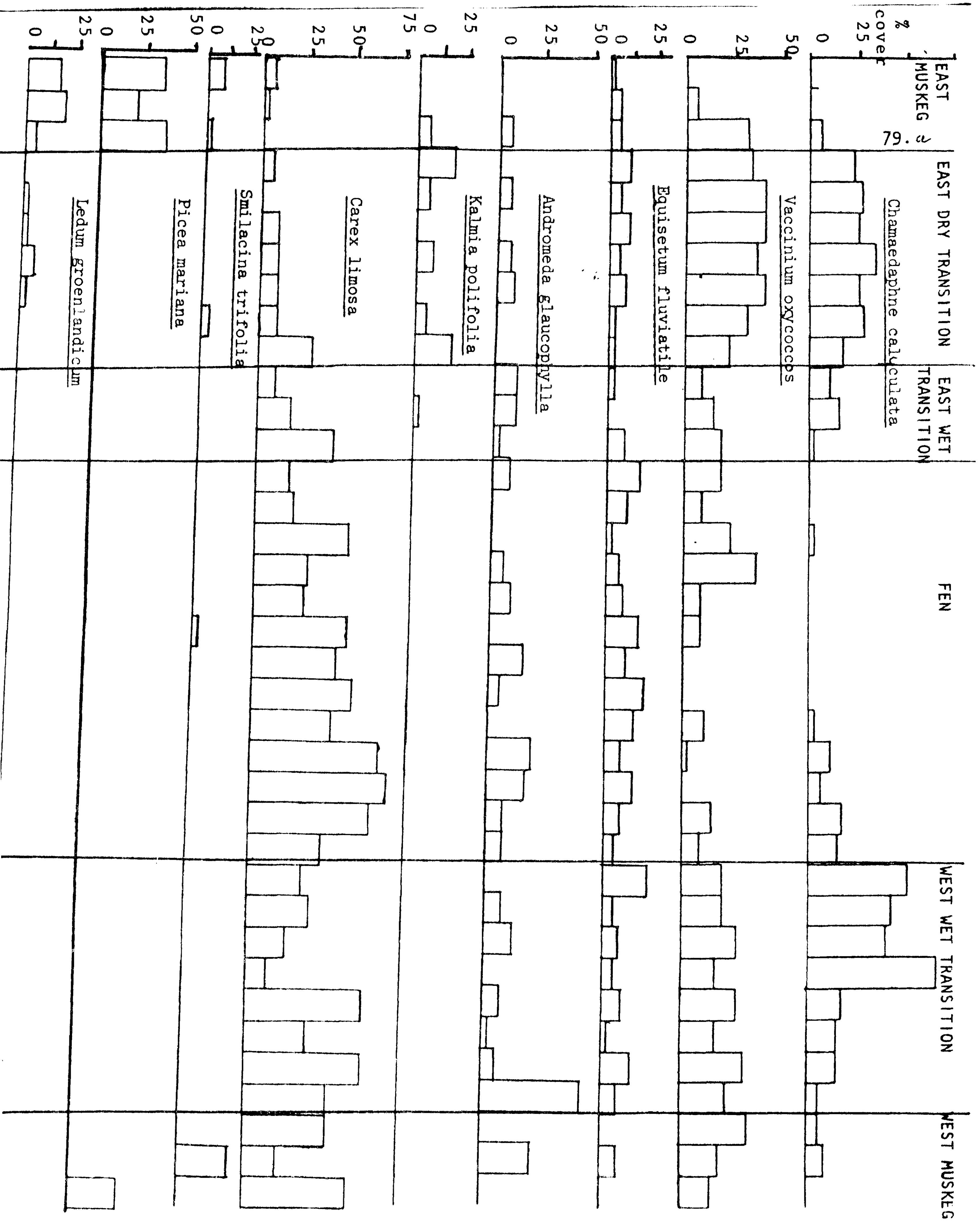


Figure R-7 Percent cover of vascular species determined by point quadrats

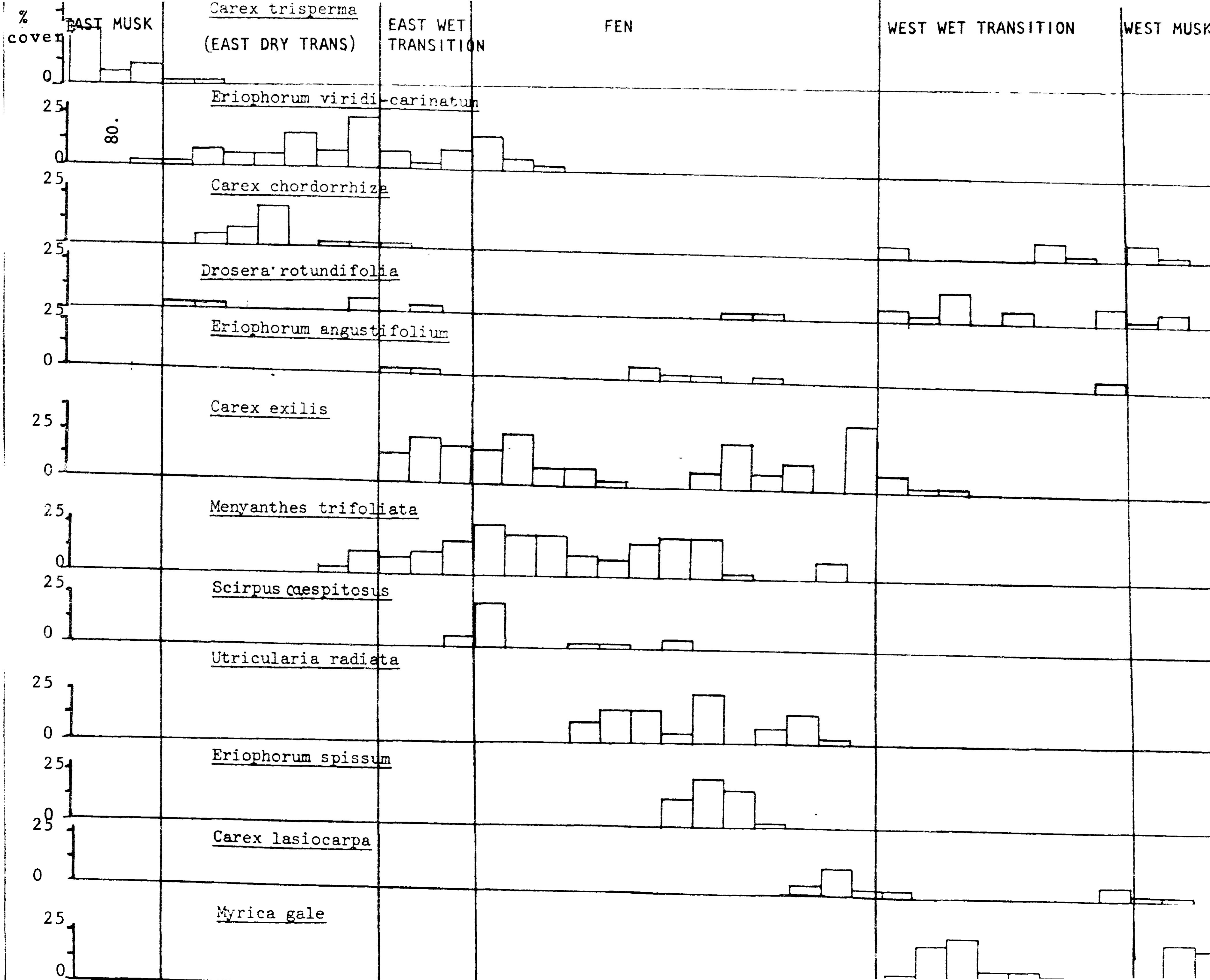


Figure R-8 Percent cover of vascular species determined by point quadrats

Table R-9 % Frequency of bryophyte species in subjectively defined units along E-W transect . Determined over consecutive three metre units.

Species	E. Musk	E. dry trans.	E. wet trans.	Fen	W. wet trans.	W. Musk.
Sphagnum magellanicum	100%	100%	33.3%	38.5%	100%	33.3%
Sphagnum fuscum	100	100	100	7.6	37.5	33.3
Sphagnum recurvum	66.6	71.4	66.6	0	100	100
Polytrichum juniperinum var. affine	33.3	85.7	0	15.4	62.5	0
Tomenthypnum nitens var falcifolium	66.6	14.3	0	7.6	0	66.6
Tomenthypnum nitens	66.6	42.9	0	7.6	0	66.6
Aulacomnium palustre	0	42.9	0	0	12.5	100
Sphagnum subsecundum	0	0	0	15.4	0	0
Drepanocladus exannulatus	0	0	0	38.5	0	0
Campylium stellatum	0	0	0	7.6	50	0

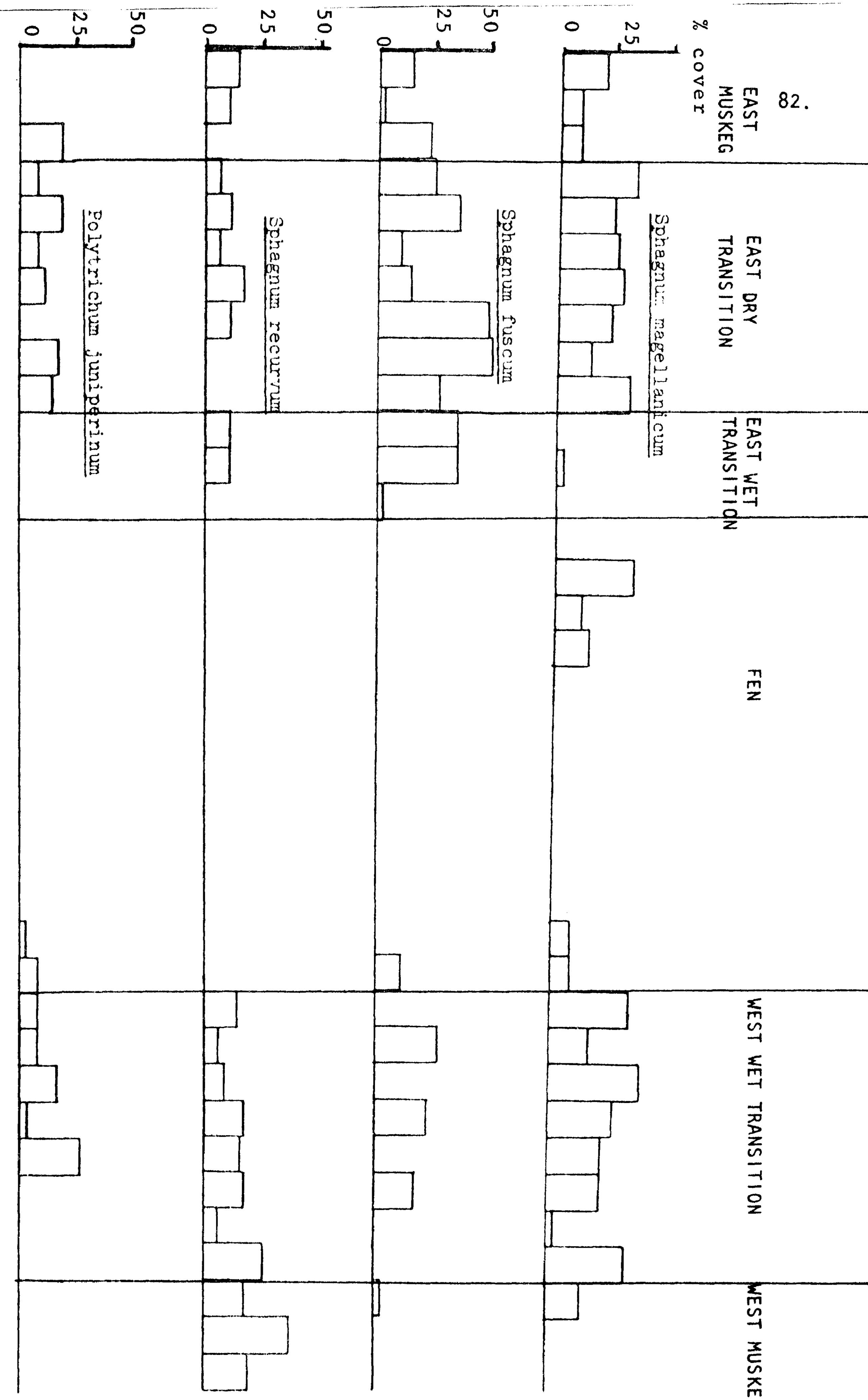


Figure R-10 Percent cover of most frequent moss species determined by point quadrats totalled over consecutive 3m sections

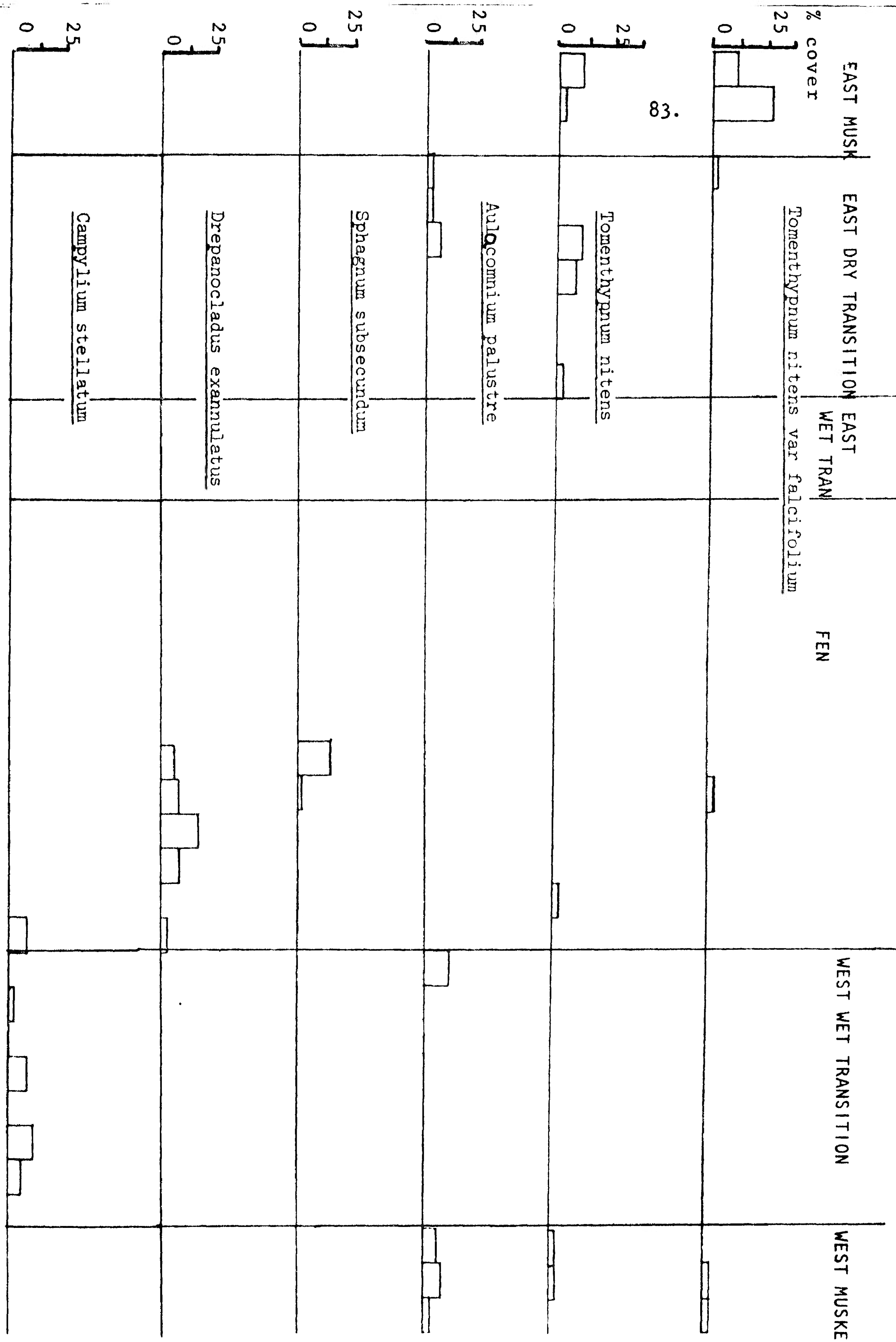


Figure R-11 Percent cover of less frequent moss species determined by point quadrats totalled over 3 m sections of level E-W transect

Chamaedaphne calyculata was most common in transition zones, east, west, wet and dry. It was least common in muskeg and fen sites. *Andromeda glaucophylla* achieved its highest cover values in wet transition zones and fen.

Although *Ledum groenlandicum* did not appear in point quadrats taken in wet transition zones or the fen, it was common to east muskeg, dry transition and west muskeg. *Kalmia polifolia* had the greatest frequency in the east dry transition zone and appeared in eastern muskeg and eastern wet transition zones. *Picea mariana* occurred exclusively in east and west muskeg sites, it appeared most frequently in the east muskeg. *Smilacina trifolia* was most frequently encountered in the eastern muskeg, however, it was also present in western muskeg, eastern dry transition zone and fen. In open sites *Smilacina trifolia* grew on the tops of well developed *Sphagnum spp.* hummocks. *Carex trisperma* occurred on the east side only, in muskeg and dry transition zones. It was commonly encountered in somewhat sheltered sites.

Eriophorum viridi-carinatum achieved its highest cover in eastern dry and wet transition zones, it was absent in western sites. This species often grew on the tops and upper edges of *Sphagnum spp.* hummocks. *Carex chordorr hiza* also grew on *Sphagnum spp.* hummocks, usually forming a cap on its top. It was most frequently encountered in the eastern dry transition zone, although it also grew on hummocks in the western muskeg and in both wet transition zones. *Drosera rotundifolia* was very common on damp sides or in sheltered sites on well developed *Sphagnum spp.* hummocks. It was most common in the western muskeg and wet transition. *Eriophorum angustifolium* was most frequently found growing in the eastern wet transition zone. Its optimum habitat appeared to be wet transitions or fen sites. *Carex exilis* appeared to have very similar habitat preferences. *Menyanthes trifoliata* occurred most frequently in the eastern wet transition and fen in very wet sites, usually the hollows between hummocks. *Scirpus caespitosus* occupied similar habitats, but, was not as common as *Menyanthes trifoliata* within the portion of the study area bisected by the transect.

Utricularia radiata and *Eriophorum spissum* were restricted to fen sites, especially in very wet hollows and in quaking mat locations.

Carex lasiocarpa and *Myrica gale* were present on the west side of the fen only. *Carex lasiocarpa* appeared most frequently in hollows in the west muskeg. *Myrica gale* dominated the western wet transition and muskeg, producing a dense shrub understorey.

Of the bryophytes encountered in point quadrats taken along the leveled transect line *Sphagnum magellanicum* appeared in every subjectively defined vegetation zone. *Sphagnum fuscum* occupied a drier habitat than *Sphagnum magellanicum* and was absent from the fen. *S. magellanicum* appeared to thrive in wetter sites, it formed very loose wet hummocks and *S. fuscum* often grew on their tops. *Sphagnum recurvum* was common on the edges of these hummocks. It was especially common on the west side of the fen. *Polytrichum juniperinum* occurred on the dry tops and sides of these hummocks. It is most frequently encountered in open sites of the eastern dry transition and western wet transition. *Tomenthypnum nitens* and *Tomenthypnum nitens var falcifolium* occupied very similar habitats on hummocks in sheltered sites. *T. nitens var falcifolium* was less often encountered in open sites. *Aulacomnium palustre* formed small hummocks on the wet edges of larger *Sphagnum spp.* hummocks. Its optimum habitat was the drier upper edges of hummocks. It was most common in the western muskeg.

Sphagnum subsecundum and *Drepanocladus exannulatus* grew exclusively in the fen in the very wettest sites. *Campylium stellatum* often formed small hummocks in wet sites in the fen and western wet transition zone.

Objective measurements of cover, for vascular and bryophyte species present along a 37 metre transect which traverses five vegetation zones, reveal that species appear to have preferred habitats and do not grow uniformly through the study area, although there was some overlap between the preferred habitats.

e) Transects A-G

(i) Subjective cover values of species sampled by quadrats

Seven transects were run from muskeg to fen. Vegetation cover was determined subjectively using a Braun-Blanquet cover scale (see Methods I). Tables R-12 through R-18 document the cover values for each species in quadrats 1-100. Braun-Blanquet values were summed for each transect and for all seven transects in Tables R-22 and R-26.

Mean Braun-Blanquet cover percentages were determined for species along transects lying east, north and west of the fen and were documented in Table R-23.

Examination of species distribution and cover along transects and around the fen from east to west was undertaken in this section of results.

Table R-12

BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

SPECIES	QUADRAT NUMBER - TRANSECT A (east side) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Picea mariana	+			4	1				4						
Larix laricina															
Thuja occidentalis															
Ledum groenlandicum				1		3		1		1					
Chamaedaphne calyculata	2	2	2	1	3	2	2	3	1	4	3	2	2	+	+
Andromeda glaucophylla	1	1			1	+					1	1	1		+
Kalmia polifolia	1	1	1		1	1	+	1		+	1				
Betula pumila															
Alnus crispa															
Salix monticola															
Lonicera villosa															
Myrica gale															
Vaccinium oxycoccos	1	1	1	+	1	2	1	2	1	1	1				3
Vaccinium vitis-idaea															
Rubus acaulis															
Smilacina trifolia		1	+	+		1	1	2			+				
Menyanthes trifoliata				+								+	1	1	1
Gaultheria hispidula												+			
Eriocaulon lividum															
Triglochin maritima															
Calla palustris															
Drosera rotundifolia			+	+									+		
Sarracenia purpurea	+										2				
Utricularia radiata														+	
Carex livida	1						2		2	3					
Carex chordorrhiza			2							1					
Carex lasiocarpa											2				
Carex gynocrates												3		3	
Carex exilis												3	4	3	
Carex limosa														1	2
Carex canescens															
Carex bromoides															
Carex trisperma															
Carex disperma															
Carex garberi															
Carex pauciflora															
Carex sp.															
Eriphorum apissum															
Eriophorum angustifolium															
Eriophorum viridi-carinatum															
Eriophorum sp.	1														
Scirpus cespitosis													1		3
Scirpus hudsonianum															
Phragmites communis															
Calamagrostis canadensis															
Equisetum fluviatile					+	'1	+					+	1	1	1
Cephalozia loitlesbergeri															
Cephalozia lunulifolia															
Odontoschisma elongatum															
Mylia anomala															
Scapania paludicola												1			
Sphagnum fuscum	4	5	1	4	5	5	2	3	1	4	5				
Sphagnum recurvum	1	1	2	2	1	2	4	1		3		3	3		3
Sphagnum recurvum var. tenue															
Sphagnum recurvun var. brevefolium															
Sphagnum magellanicum	1	2	2				3	2	5		1	4	3	6	2
Sphagnum capillifolium									2						
Sphagnum wulfianum															
Polytrichum juniperinum var affine	1	2	+	1			1	1		1	+				
Aulacomnium palustre			1		2	2	1	+							+
Campylium stellatum			+										2		
Dicranum polysetum							+								
Pleurozium schreberi								+							
Pohlia nutans															
Drepanocladus uncinatus															
Drepanocladus revolvens															
Tomenthypnum nitens															
Tomenthypnum nitens var. falcifolium							1								
Rhizomnium pseudopunctatum															
Scorpidium scorpioides															
[illegible]					1										
[illegible]					1										

Table R-13

BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

SPECIES	QUADRAT NUMBER - TRANSECT B (east side)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Picea mariana	2		2	2	4		3	2							
Larix laricina			+		2					1					3
Thuja occidentalis															
Kalmia polifolia			+	1		1	1	2	1	2	1		1	2	1
Ledum groenlandicum	2	2			1		1								
Chamaedaphne calyculata		2	3	4	1	3	2	3	2	2	2	1	1	1	1
Andromeda glaucophylla											1	1		3	1
Betula pumila															
Alnus crispa															
Salix monticola															
Lonicera villosa															
Myrica gale															
Vaccinium oxycoccos		1	+	1	1		3	2	1	1	2	1	2	1	1
Vaccinium vitis-idaea	+	1			+										
Rubus acaulis															
Smilicina trifolia		2	2	2	1		1	1	+	1	2	1			
Menyanthes trifoliata												2			
Gaultheria hispidula	+														
Geocaulon lividum	+														
Triglochin maritima															
Calla palustris															
Drosera rotundifolia											+			1	1
Sarracena purpurea															
Utricularia radiata												1			
Carex livida						1					1			2	
Carex chordorrhiza	+						1					1	1	1	
Carex lasiocarpa															
Carex gymnocarates													1	1	
Carex exilis															
Carex limosa												3	3	2	
Carex canescens															
Carex bromoides															
Carex trisperma															
Carex disperma															
Carex garberi															
Carex pauciflora															
Carex sp.															
Eriophorum spissum													1		
Eriophorum angustifolium													1		2
Eriophorum viridi-carinatum															
Eriophorum sp.									1						
Scirpus cespitosis												1			
Scirpus hudsonianum															
Phragmites communis															
Calamagrostis canadensis															
Equisetum fluviatile						+		+	1	1	1	1	1	1	1
Cephalozia loitlesbergi					1										
Cephalozia lunulifolia															
Odontoschisma elongatum					1										
Mylia anomala															
Scapania paludicola					1										
Sphagnum fuscum			2	2		5	3	4	1	5	2			2	
Sphagnum recurvum		4	2			5	2		5		5	2			
Sphagnum magellanicum	4	3	4		3		1	1		1		3	3	5	3
Sphagnum capillifolium		1		2	2										
Sphagnum wulfianum															
Polytrichum juniperinum var. *affine*		+	1		3			1		1	1			1	
Aulacomnium palustre				3		2									
Campyllium stellatum															
Dicranum polysetum															
Pleurozium schreberi					1										
Pohlia nutans				3											
Drepanocladus uncinatus															
Drepanocladus revolvens															
Tomenthypnum nitens															
Tomenthypnum nitens var. *falcifolium*										1					
Rhizomnium pseudopunctatum															
Scorpidium scorpoides															
Calicladium haldanianum															
Ceratadon purpureus															

Table R-14

BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

SPECIES	QUADRAT NUMBER - TRANSECT C (north side)															
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Picea mariana	2	5	2	4		3	4		1							
Larix laricina			+				4									
Thuja occidentalis																
Ledum groenlandicum		+	2		2	1										
Chamaedaphne calyculata	1	2	3	4	2	2	2	2	3	2	2		2	1	1	1
Andromeda glaucophylla		1		1			1	3		2		1	2	2		1
Kalmia polifolia	1															
Betula pumila																
Alnus crispa																
Salix monticola																
Lonicera villosa																
Myrica gale										+	1	2		1		
Vaccinium oxycoccos	1	1	5	2		1		1	1	1		1	1	1	1	
Vaccinium vitis-idaea																
Rubus acaulis																
Smilacina trifolia						1		+	1	2	2					
Menyanthes trifoliata															1	2
Gaultheria hispidula																
Geocaulon lividum																
Triglochin maritima																
Calla palustris																
Drosera rotundifolia			+			+							1			
Sarracenia purpurea								+				1				
Utricularia radiata															1	2
Carex livida				2			1					2			1	
Carex chordorrhiza										2					2	
Carex lasiocarpa																
Carex gymnocarates														2		2
Carex exilis																
Carex limosa	4	3	3		5		3		+	2	3		4			2
Carex canescens																
Carex bromoides																
Carex trisperma																
Carex disperma																
Carex garberi																
Carex pauciflora																
Carex sp.				2												
Eriophorum spissum																
Eriophorum angustifolium																
Eriophorum viridi-carinatum																
Eriophorum sp.													1			
Scirpus cespitosis																
Scirpus hudsonianum																
Phragmites communis																
Calamagrostis canadensis																
Equisetum fluviatile				+			+		1	+	1	1	1	1	1	1
Cephalozia loitlesbergi																
Cephalozia lunulifolia																
Odontoschisma elongatum																
Mylia anomala																
Scapania paludicola																
Sphagnum fuscum	3	2	3		4	2		5	5	1	3	4	3	3		
Sphagnum recurvum	3	2	3	4	3	2	2				3		3	3		
Sphagnum recurvum var. tenue		2														
Sphagnum magellanicum		3		2			3	2		2	1	4	2	2	3	2
Sphagnum capillifolium				2	3						3					
Sphagnum wulfianum																
Polytrichum juniperinum var. affine	1	1		1			1	1	1	1				1		
Aulacomnium palustre			1													
Campylium stellatum																
Dicranum polysetum						1										
Pleurozium schreberi																
Pohlia nutans																
Drepanocladus uncinatus		1														
Drepanocladus revolvens																
Tomenthypnum nitens																
Tomenthypnum nitens var falcifolium																
Rhizomnium pseudopunctatum																
Scorpidium scorpoides																
Callicladium haldanianum																
Ceratadon purpureus																

Table R-15

BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

SPECIES — QUADRAT NUMBER - TRANSECT D (north side)	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Picea mariana		1	1	1	4	2	3	2							
Larix laricina							+								
Thuja occidentalis															
Ledum groenlandicum	1	1	1			1	2	1			2				
Chamaedaphne calyculata	4	2	4	3	3	3	5	2	3	2	3	1	1	1	
Andromeda glaucophylla		1			1				1	1	1		1	1	2
Kalmia polifolia		1	1		1	1		1	1	1		1	1	1	1
Betula pumila															
Alnus crispa															
Salix monticola															
Lonicera villosa															
Myrica gale															
Vaccinium oxycoccos	1	1	1			1	1	1	1	1	1	1			+
Vaccinium vitis-idaea															
Rubus acaulis															
Smilicina trifolia		1	1	1			1	2		2	1	1	3		
Menyanthes trifoliata															
Gaultheria hispidula															
Geocaulon lividum	1														
Triglochin maritima															
Calla palustris															
Drosera rotundifolia		+					1					1	+		+
Saracenia purpurea										+			1		
Utricularia radiata															
Carex livida															
Carex chordorrhiza			3						2			4	2		2
Carex lasiocarpa															
Carex gymnocarates															
Carex exilis														1	
Carex limosa	3	+	1	1		+			+	1			1	3	3
Carex canescens				1			+				1				
Carex bromoides						+									
Carex trisperma															
Carex disperma															
Carex pauciflora															
Carex sp.															
Eriophorum spissum															
Eriophorum angustifolium															
Eriophorum viridi-carinatum															1
Eriophorum sp.												1	1		
Scirpus cespitosus							1								
Scirpus hudsonianum															
Phragmites communis															
Calamagrostis canadensis															
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Equisetum fluviatile						1	1	1	1	1	1		1	1	1
Cephalozia loitlesbergi															
Cephalozia lunulifolia															
Odontoschisma elongatum															
Mylia anomala															
Scapania paludicola															
Sphagnum fuscum			5			2			2	5	2	3	5		4
Sphagnum recurvum	2	3		2		4	2	5	3	2	4	3	3		2
Sphagnum magellanicum	1	2		2			2			1		1	1	2	2
Sphagnum capillifolium															
Sphagnum wulfianum															
Polytrichum juniperinum var affine									2	1	2	1	1		1
Aulacomnium palustre		1			1										
Campylium stellatum							1								
Dicranum polysetum								1			1				
Pleurozium schreberi							1	1							
Pohlia nutans															
Drepanocladus uncinatus															
Drepanocladus revolvens															
Tomenthypnum nitens					1				1						
Tomenthypnum nitens var falcifolium								1							
Rhizomnium pseudopunctatum															
Scorpidium scorpoides															
Calicladium haldanianum															
Ceratodon purpureus															

Table R-16

BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS
QUADRAT NUMBER - TRANSECT E (west side)

SPECIES	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Picea mariana	2	4	5	4	2	1								
Larix laricina					1	1							3	
Thuja occidentalis														
Ledum groenlandicum	2	1		1	3	1								
Chamaedaphne calyculata	1				1	1	2	3	1	1	+	1	1	2
Andromeda glaucophylla						1	+	1	1		+	1	1	
Kalmia polifolia					+	1		1		1	+	1	1	1
Betula pumila														
Alnus crispa									1					
Salix monticola							+							
Lonicera villosa														
Myrica gale	2				3	3	3	3	2					
Vaccinium oxycoccos	1					1	1	1	1	1	1	1	1	1
Vaccinium vitis-idaea	1			1										
Rubus acaulis														
Smilicina trifolia	+	1		+		1								
Menyanthes trifoliata									2	3	3	2		
Gaultheria hispidula														
Geocaulon lividum														
Triglochin maritima										1				
Calla palustris														
Drosera rotundifolia							1	1	2		1			
Sarracenia purpurea						1						2		
Utricularia radiata														
Carex livida														
Carex chordorrhiza							1				2			
Carex lasiocarpa														
Carex gymnocrates														
Carex exilis											2	4	3	
Carex limosa				3					4	3	2		2	
Carex canescens														
Carex bromoides														
Carex trisperma		4												
Carex disperma			1											
Carex pauciflora														
Carex garberi						3		3						
Carex sp.	2													
Eriophorum spissum														
Eriophorum angustifolium														
Eriophorum viridi-carinatum								+						
Eriophorum sp.														
Scirpus cespitosus														
Scirpus hudsonianum							1							
Phragmites communis							1	+						
Calamagrostis canadensis		+												
Equisetum fluviatile				+	+	1	1	1	1	1	1	1	1	1
Cephalozia loitlesbergi														
Cephalozia lunulifolia														
Odontoschisma elongatum														
Mylia anomala														
Scapania paludicola														
Sphagnum fuscum				2			3							
Sphagnum recurvum	1	1			1			4	2				1	1
Sphagnum recurvum var. *tenue*						2								
Sphagnum recurvum var. *brevafolium*														
Sphagnum magellanicum						3	3	2	3		4	5	5	3
Sphagnum capillifolium														
Sphagnum wulfianum			1		2									
Polytrichum juniperinum var *affine*														
Aulacomnium aplustre					1	1		1						
Campyllium stellatum														
Dicranum polysetum	1													
Pleurozium schreberi	2	5	2	3	3									
Pohlia nutans														
Drepanocladus uncinatus														
Drepanocladus revolvens														
Tomenthypnum nitens		1		1	1			1	1					
Tomenthypnum nitens var. *falcifolium*		1			1									
Rhizomnium pseudopunctatum			1		1									
Scorpidium scorpioides														
Calicladium haldanianum														
Ceratodon purpureus														

Table R-17 BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

SPECIES	QUADRAT NUMBER - TRANSECT F (west side)													
	76	77	78	79	80	81	82	83	84	85	86	87	88	89
Picea mariana		3	3	3										
Larix laricina	2	2					2							
Thuja occidentalis	2													
Ledum groenlandicum	2	4	3	3	2			1						
Chamaedaphne calyculata	1				1		4	2		2				
Andromeda glaucophylla	3	1	2		3	3	3	1	3	2	1	2		1
Kalmia polifolia		1			1									
Betula pumila	2			2	2									
Alnus crispa			2	2										
Salix monticola							1			1				
Lonicera villosa	2													
Myrica gale	3	1	2	3		2	2	2	1	2				
Vaccinium oxycoccos	1	1	1	1	1	1	2	1	2	1				
Vaccinium vitis-idaea														
Rubus acaulis	1	1			1									
Sarracenia purpurea									1					1
Drosera rotundifolia				1		1	1	1	2					
Utricularia radiata									1		1		1	2
Smilicina trifolia	1			2										
Menyanthes trifoliata							2	2	2	1	1	1		1
Gaultheria hispidula														
Geocaulon lividum														
Triglochin maritima														
Calla palustris								2		1				
Carex livida														
Carex chordorrhiza	3				3			2						
Carex lasiocarpa														
Carex gymnocarates														
Carex exilis											4	5		2
Carex limosa		2		1		3		2		4	3	2		
Carex canescens														
Carex bromoides														
Carex trisperma														
Carex disperma			1											
Carex garberi														
Carex pauciflora					3									
Carex sp.														3
Scirpus cespitosis					2									
Scirpus hudsonianum						2	1		4					
Eriophorum spissum													2	3
Eriophorum angustifolium						1								
Eriophorum viridi-carinatum														
Eriophorum sp.														
Phragmites communis									1		1	2		1
Calamagrostis canadensis	1	1	1					1	1					
Equisetum fluviatile				+	1	1	1	1	1	1	1		2	2
Cephalozia loitlesbergi														
Cephalozia lunulifolia														
Odontoschisma elongatum														
Mylia anomala														
Scapania paludicola														
Sphagnum fuscum		5	4		2			1	3	4				
Sphagnum recurvum				2				2				2		
Sphagnum recurvum var brevefolium														
Sphagnum recurvum var tenue														
Sphagnum magellanicum								2		2				2
Sphagnum capillifolium														
Sphagnum wulfianum		1		1	1									
Polytrichum juniperinum var. affine														
Aulacomnium palustre	1				1		2	1		2				
Campylium stellatum						3		3	3					
Dicranum polysetum			1	2	1									
Pleurozium schreberi	5	2	4	4	2									
Pohlia nutans														
Drepanocladus uncinatus														
Drepanocladus revolvens				2										
Tomenthypnum nitens	2	1	1	1			3							
Tomenthypnum nitens var. falcifolium														
Rhizomnium pseudopunctatum														
Scorpidium scorpioides														
Calicladium haldanianum														
Ceratadon purpureus														

Table R-18 BRAUN-BLANQUET COVER OF SPECIES PRESENT IN 25 x 100 cm QUADRATS

QUADRAT NUMBER - TRANSECT G (east side)

SPECIES	90	91	92	93	94	95	96	97	98	99	100
Picea mariana	2			3						1	
Larix laricina								1			
Thuja occidentalis											
Ledum groenlandicum	2	1	1			1			2		
Chamaedaphne calyculata	3	3	2	2	2	3	1	1	2	3	3
Andromeda glaucophylla	1	2	2	2	1		1	2	1	1	2
Kalmia polifolia		1	1	1	1	1	1	1		2	1
Betula pumila											
Alnus crispa											
Salix monticola											
Lonicera villosa											
Myrica gale											
Vaccinium oxycoccos	3	4	3	3	2	3	2	1	2	2	2
Vaccinium vitis-idaea											
Rubus acaulis											
Smilacina trifolia				1		1	1		1		
Menyanthes trifoliata					+						
Gaultheria hispidula											
Geocaulon lividum											
Triglochin maritima								2			
Calla palustris											
Sarracenia purpurea						1			1	1	
Drosera rotundifolia	1		1	2	1	1		1	1		
Utricularia radiata											
Carex livida											
Carex chordorrhiza	4	1	2	3	2	2		2	1	2	2
Carex lasiocarpa											
Carex gynmocrates											
Carex exilis											
Carex limosa			2	3		2	4		2	1	
Carex canescens											
Carex bromoides											
Carex trisperma	1										
Carex disperma											
Carex garberi											
Carex pauciflora											
Eriophorum spissum											
Eriophorum angustifolium											
Eriophorum viridi-carinatum		2	1		3		2			2	2
Eriophorum sp.											
Scirpus cespitosus									3	2	
Scirpus hudsonianum											
Phragmites communis						2					
Calimagrostis canadensis											
Equisetum fluviatile	1	1	1	1	1	1	1	2	1	1	1
Cephalozia loitlesbergi											
Cephalozia lunulifolia	2										
Odontoschisma elongatum											
Mylia anomala						1					
Scapania paludicola											
Sphagnum fuscum	3	5	4	4	2	4		2	4	4	5
Sphagnum recurvum							2				
Sphagnum recurvum var. *tenue*		2	2	2		2		2	2	4	
Sphagnum recurvum var. *brevefolium*	2										
Sphagnum magellanicum	2	2	2	1	2	2	2	4	2	1	2
Sphagnum capillifolium											
Sphagnum wulfianum											
Polytrichum juniperinum var. *affine*	2	2	2	1	1	1		1	1	1	2
Aulacomnium palustre			1	1		1					
Campylium stellatum					2		3	2	2		
Dicranum polysetum											
Pleurozium schreberi											
Pohlia nutans											
Drepanocladus uncinatus											
Drepanocladus revolvens											
Tomenthypnum nitens	1					1					
Tomenthypnum nitens var. *falcifolium*											
Rhizomnium pseudopunctatum											
Scorpidium scorpioides								2			
Calicladium haldanianum											
Ceratodon purpureus											

Table R-19 Subjective classification of quadrats 1-100

Transect	Quadrat	Subjective classification			Number
A	5-10	east	muskeg	(E-M)	11
B	16-20	east	muskeg		
C	31-34	north	muskeg	(N-M)	9
D	47-51	north	muskeg		
E	62-65	west	muskeg	(W-M)	8
F	76-79	west	muskeg		
A	1-4, 11,12	east	transition	(E-T)	23
B	21-26	east	transition		
G	90-100	east	transition		
C	35-44	north	transition	(N-T)	16
D	52-57	north	transition		
E	66-69	west	transition	(W-T)	10
F	80-85	west	transition		
A	13-15	east	fen	(E-F)	7
B	27-30	east	fen		
C	45-46	north	fen	(N-F)	6
D	58-61	north	fen		
E	70-75	west	fen	(W-F)	10
F	86-89	west	fen		
					100 Total

Table R-20

PRESENCE OF SPECIES IN TRANSECTS A - G

VASCULAR SPECIES	(15) A	(15) B	(16) C	(15) D	(14) E	(14) F	(11) G	(100) TOTAL -- # QUADRATS
Picea mariana	4	6	7	7	6	3	3	36
Larix laricina		4	2	1	3	2	1	13
Thuja occidentalis						1		1
Ledum groenlandicum	4	4	4	7	5	6	5	35
Chamaedaphne calyculata	15	14	15	14	11	5	11	85
Andromeda glaucophylla	8	4	9	8	7	12	10	58
Kalmia polifolia	9	11	1	11	8	2	9	51
Betula pumila						3		3
Alnus crispa					1	2		3
Salix monticola					1	2		3
Lonicera villosa						1		1
Myrica gale			4		6	9		19
Vaccinium oxycoccos	12	13	12	11	10	10	11	79
Vaccinium vitis-idaea		3			2			5
Rubus acaulis						3		3
Smilacina trifolia	7	10	5	9	4	2	4	41
Menyanthes trifoliata	4	1	2		4	7	1	19
Gaultheria hispidula	1	1						2
Geocaulon lividum		1						2
Triglochin maritima					1		1	2
Calla palustris						2		2
Drosera rotundifolia	3	3	3	5	4	5	3	26
Sarracenia purpurea	2		2	2	2	2	7	17
Utricularia radiata	1	1	2			4		8
Carex livida	4	3	4					11
Carex chordorrhiza	2	5	2				10	29
Carex lasiocarpa	1							1
Carex gynocrates	2	2	2					6
Carex exilis	3			1	3	3		10
Carex limosa	2	3	10	10	5	7	6	43
Carex canescens				3				3
Carex bromoides				1				1
Carex trisperma					1			2
Carex disperma					1			2
Carex garberi					2			2
Carex pauciflora						1		1
Carex sp.						1		2
Eriophorum spissum		1				2		4
Eriophorum angustifolium		2				1		3
Eriophorum viridi-carinatum				1			6	8
Eriophorum sp.	1	1		2				5
Scirpus caespitosis	2	1		1		1	2	7
Scirpus hudsonianum					1	3		4
Phragmites communis					2	4	2	8
Calamagrostis canadensis					1	5		6
Equisetum fluviatile	7	9	10	9	11	10	11	67

The vascular species present in 30 or more quadrats were, *Chamaedaphne calyculata*, *Vaccinium oxycoccos*, *Equisetum fluviatile*, *Andromeda glaucophylla*, *Kalmia polifolia*, *Carex limosa*, *Smilacina trifolia*, *Picea mariana*, and *Ledum groenlandicum*. Of these species *Chamaedaphne calyculata* had the highest total cover value of 173.75 of a possible 500 Braun-Blanquet units. (See Table R-22.) *Vaccinium oxycoccos* had a total cover value of 108.75, *Carex limosa* 104.0, *Picea mariana* 93.0, *Andromeda glaucophylla* 81.0, *Equisetum fluviatile* 60.75, *Ledum groenlandicum* 56.25, and *Smilacina trifolia* 47.75.

Mean cover values per transect (see Table R-23) varied with transect location for some frequently occurring vascular species. *Chamaedaphne calyculata* and *Vaccinium oxycoccos* had higher cover on the north and east sides of the fen. *Ledum groenlandicum* and *Andromeda glaucophylla* had higher cover on the west side of the fen. *Kalmia polifolia* achieved its highest cover value on the east side of the fen. *Carex limosa* had higher mean cover values on the north and west side of the fen. *Carex chordorrhiza* had higher cover values on the north and east side of the fen.

Some less frequently occurring vascular species exhibit dramatic differences in mean cover value between transect location. Most noticeable was *Myrica gale*, absent in the east, low (2.1) in the north and highest (17.0) in the west. *Menyanthes trifoliata* and *Carex exilis* behaved in a similar manner.

Vegetational composition and species cover appearedto vary with transect location, as well as, along the transect as it went from muskeg to fen.

continued on page 102.

Table R-21

VASCULAR SPECIES RANKED BY PERCENT PRESENCE (INCL. THOSE WITH AT LEAST 5%)

SPECIES	%PRESENCE
Chamaedaphne calyculata	85 %
Vaccinium oxycoccos	79
Equisetum fluviatile	67
Andromeda glaucophylla	58
Kalmia polifolia	51
Carex limosa	43
Smilacina trifolia	41
Picea mariana	36
Ledum groenlandicum	35
Carex chordorrhiza	29
Drosera rotundifolia	26
Myrica gale	19
Menyanthes trifoliata	19
Sarracenia purpurea	17
Larix laricina	13
Carex livida	11
Carex exilis	10
Utricularia radiata	8
Eriophorum viridi-carinatum	8
Phragmites communis	8
Calamagrostis canadensis	6
Carex gynocrates	6
Eriophorum sp.	5
Vaccinium vitis-idaea	5

Table R-22 Total Braun-Blanquet Cover of Vascular Species Per Transect (arranged according to frequency)

MAXIMUM POSSIBLE COVER = 500

COVER VALUE OF + = 0.25

SPECIES \ TRANSECT	A	B	C	D	E	F	G	TOTAL
Chamaedaphne calyculata	29.5	28.0	30.0	37.0	14.25	10.0	25.0	173.75
Vaccinium oxycoccos	15.25	17.25	17.0	10.25	10.0	12.0	27.0	108.75
Equisetum fluviatile	4.75	7.5	7.75	9.0	9.5	11.25	11.0	60.75
Andromeda glaucophylla	6.5	6.0	14.0	9.0	5.5	25.0	15.0	81.0
Kalmia polifolia	7.5	13.25	1.0	11.0	6.5	2.0	10.0	51.25
Carex limosa	8.0	8.0	29.25	13.75	14.0	17.0	14.0	104.0
Smilacina trifoliata	5.75	13.25	6.25	13.0	2.5	3.0	4.0	47.75
Picea mariana	9.25	15.0	21.0	14.0	18.0	10.0	6.0	93.25
Ledum groenlandicum	6.0	6.0	5.25	9.0	8.0	15.0	7.0	56.25
Carex chordorrhiza	3.0	4.25	4.0	13.0	3.0	8.0	21.0	56.25
Drosera rotundifolia	0.75	2.25	1.5	2.75	5.0	6.0	8.0	26.25
Myrica gale	0	0	4.25	0	16.0	18.0	0	26.3
Menyanthes trifoliata	3.5	2.0	3.0	0	10.0	10.0	0.25	28.75
Sarracenia purpurea	2.25	0	1.25	1.25	3.0	2.0	3.0	12.75
Larix laricina	0	6.25	4.25	0.25	5.0	6.0	1.0	22.75
Carex livida	8.0	4.0	6.0	0	0	0	0	18.0
Carex exilis	10.0	0	0	1.0	9.0	11.0	0	31.0
Utricularia radiata	0.25	1.0	3.0	0	0	5.0	0	9.25
Eriophorum viridi-carinatum	0	0	0	1.0	0.25	0	12.0	13.25
Phragmites communis	0	0	0	0	1.25	5.0	2.0	8.25
Calamagrostis canadensis	0	0	0	0	0.25	5.0	0	5.25
Carex gynocrates	6.0	2.0	4.0	0	0	0	0	12.0
Eriophorum sp.	1.0	1.0	1.0	2.0	0	0	0	5.0
Vaccinium vitis-idaea	0	1.5	0	0	2.0	0	0	3.5

Table R-23 Per cent of total Braun-Blanquet cover possible for species in transects located east, north and west of the fen

SPECIES \ TRANSECT	EAST (A, B, G) Max poss. cover 66.5 BB units	NORTH (C, D) Max poss. cover 77.5 BB units	WEST (E, F) Max poss. cover 72.5 BB units
Larix laricina	3.6%	2.9%	7.5%
Picea mariana	15.2	22.6	19.3
Ledum groenlandicum	9.6	9.2	15.9
Vaccinium vitis-idaea	0.8	0	1.5
Vaccinium oxycoccos	29.8	17.8	15.2
Chamaedaphne calyculata	41.4	43.2	24.1
Kalmia polifolia	15.4	7.7	5.9
Andromeda glaucophylla	13.8	14.8	21.0
Equisetum fluviatile	11.7	10.8	14.3
Smilacina trifolia	11.6	12.4	3.9
Menyanthes trifoliata	2.9	1.9	13.8
Sarracenia purpurea	2.6	1.6	3.4
Drosera rotundifolia	5.6	2.7	7.5
Utricularia radiata	0.6	1.9	3.4
Myrica gale	0	2.7	23.4
Carex limosa	15.0	27.7	21.4
Carex chordorrhiza	14.3	11.0	7.5
Carex livida	6.0	3.9	0
Carex exilis	5.0	0.6	13.8
Carex gynocrates	3.9	2.6	0
Eriophorum viridi-carinatum	6.0	0.6	0.1
Calamagrostis canadensis	0	0	3.5
Phragmites communis	0.9	0	4.3
Sphagnum magellanicum	42.1	25.8	23.4
Sphagnum fuscum	52.3	42.5	16.6
Sphagnum recurvum	26.6	40.6	11.7
Polytrichum juniperinum var affine	14.8	10.3	0

Presence of bryophyte species encountered in transects A-G was outlined in Table R-24. Table R-25 gives the total per cent presence of bryophyte species which occurred in more than 5 quadrats. Most frequently encountered were the *Sphagnum* species which blanket the study area. *Sphagnum magellanicum* was found most frequently (64 quadrats out of a possible 100), *Sphagnum fuscum* next frequently (58 quadrats) and *Sphagnum recurvum* appeared in 52 quadrats. *Polytrichum juniperinum var affine* was very common (39 quads), especially on the tops of *Sphagnum fuscum* capped hummocks.

Highest total cover was achieved by *Sphagnum fuscum*, 192 out of a possible 500 Braun-Blanquet units as outlined in Table R-26. When transects were grouped by location and mean cover values were calculated (Table R-23) *Sphagnum spp.* cover appeared to vary with transect location. *Sphagnum magellanicum* had highest cover on the east side and least on the west. *Sphagnum fuscum* cover was similar on the north and east side and lowest on the west. *Sphagnum recurvum* had highest cover in the north and least in the west. *Polytrichum juniperinum* was absent in quadrats on the west side and had similar cover values on the north and east side of the fen.

Species cover in both frequently occurring bryophytes and vasculars appeared to vary with location of the transect in relation to the fen's centre. The west side was not as rich in bryophytes as the north and east sides were.

Table R-24

PRESENCE OF SPECIES IN TRANSECTS A - G

BRYOPHYTE SPECIES	(15) A	(15) B	(16) C	(15) D	(14) E	(14) F	(11) G	(100) TOTAL -- # QUADRATS
Cephalozia loitlesbergi		1						1
Cephalozia lunulifolia								1
Odontoschisma elongatum		1						1
Mylia anomala								1
Scapania paludicola	1	1						2
Sphagnum fuscum	11	9	12	8	2	6	10	58
Sphagnum recurvum	12	7	10	12	7	3	1	52
Sphagnum recurvum var. brevefolium							1	1
Sphagnum recurvum var tenue			1		1		7	9
Sphagnum magellanicum	11	11	11	9	8	3	11	64
Sphagnum capillifolium	1	3	3					7
Sphagnum wulfianum					2	3		5
Polytrichum juniperinum var. affine	8	7	8	6			10	39
Aulacomnium palustre	6	2	1	2	3	5	3	22
Campylium stellatum	2			1		3	4	10
Dicranum polysetum	1		1	2	1	2		7
Pleurozium schreberi	1	1		2	5	5		14
Pohlia nutans		1						1
Drepanocladus uncinatus								1
Drepanocladus revolvens						1		1
Tomenthypnum nitens				2	5	5	2	14
Tomenthypnum nitens var. falcifolium	1			1	2			5
Rhizomnium pseudopunctatum					2			2
Scorpidium scorpioides								1
Calicladium haldanianum	1							1
Ceratadon purpureus	1							1

Table R-25

BRYOPHYTE SPECIES RANKED BY PERCENT PRESENCE (INCL. THOSE WITH MORE THAN 5%)

SPECIES	% PRESENCE
Sphagnum magellanicum	64
Sphagnum fuscum	58
Sphagnum recurvum	52
Polytrichum juniperinum var. affine	39
Aulacomnium palsutre	22
Pleurozium schreberi	14
Tomenthypnum nitens	14
Campy lium stellatum	10
Dicranum polysetum	7
Tomenthypnum nitens var falcifolium	5

Table R-26 Total Braun-Blanquet cover of Bryophyte Species Per transect (arranged according to frequency)

MAXIMUM POSSIBLE COVER = 500

SPECIES \ TRANSECT	A	B	C	D	E	F	G	TOTAL
Sphagnum magellanicum	31.0	31.0	26.0	14.0	28.0	6.0	22.0	158.0
Sphagnum fuscum	39.0	26.0	38.0	28.0	5.0	19.0	37.0	192.0
Sphagnum recurvum	26.0	25.0	28.0	35.0	11.0	6.0	2.0	133.0
Polytrichum juniperinum var affine	7.5	8.25	8.0	8.0	0	0	14.0	45.75

(ii) Ordination of quadrats from transects A-G

Presence-absence floristic data from quadrats 1-100, transects A-G was subjected to Bray and Curtis Ordination (see Methods section) which resulted in a two dimensional ordination of quadrats.

Figure R-28 is the resultant plot of labelled quadrats along X and Y ordination axes. There appeared to be no distinct grouping of quadrats, rather there was a continuous scatter of points.

Quadrats were identified by their location in relation to the fen, and whether they fell into subjectively defined muskeg, transition or fen sites, and plotted on the ordination in Figure R-29. Grouping of similar quadrats was now evident as lines were drawn between locations and site types. (See figure R-30.) Fen quadrats comprise a single group and were not separated by location in relation to the fen's centre. Quadrats that were not within their subjective classification unit were circled and labelled.

Muskeg sites had the lowest X-axis locations in relation to their transition and fen sites. West side muskeg quadrats further along the x axis than northern or eastern muskeg quadrats. East side quadrats had the lowest Y-axis locations while west side quadrats had the highest Y axis values.

The general trend in the ordination X axis was to sort quadrats from muskeg to transition to fen types. The trend in the Y axis was to sort quadrats from east to north to west. This sorting resulted

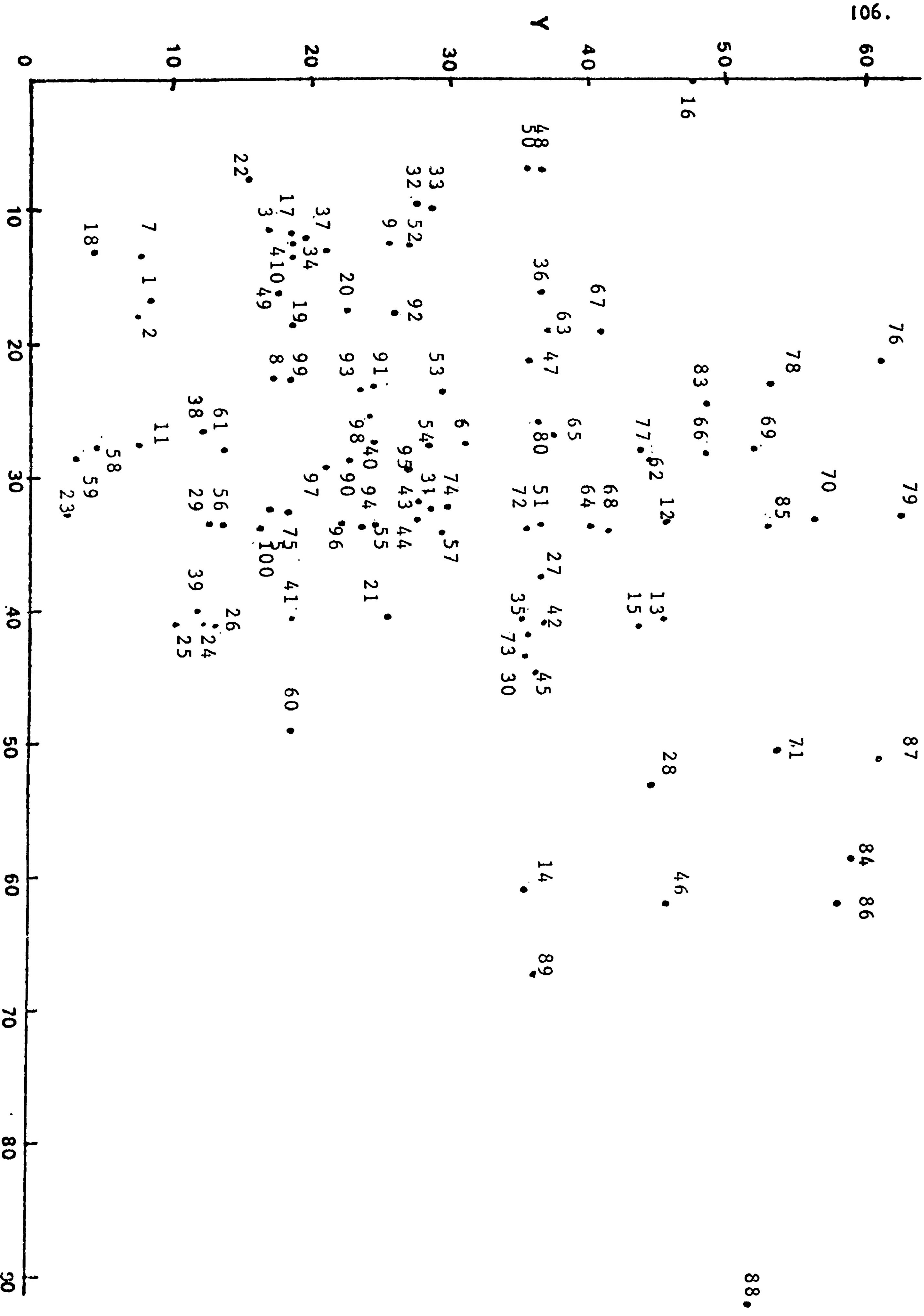


Figure R-28 Bray and Curtis (1957) ordination of quadrats 1 to 100

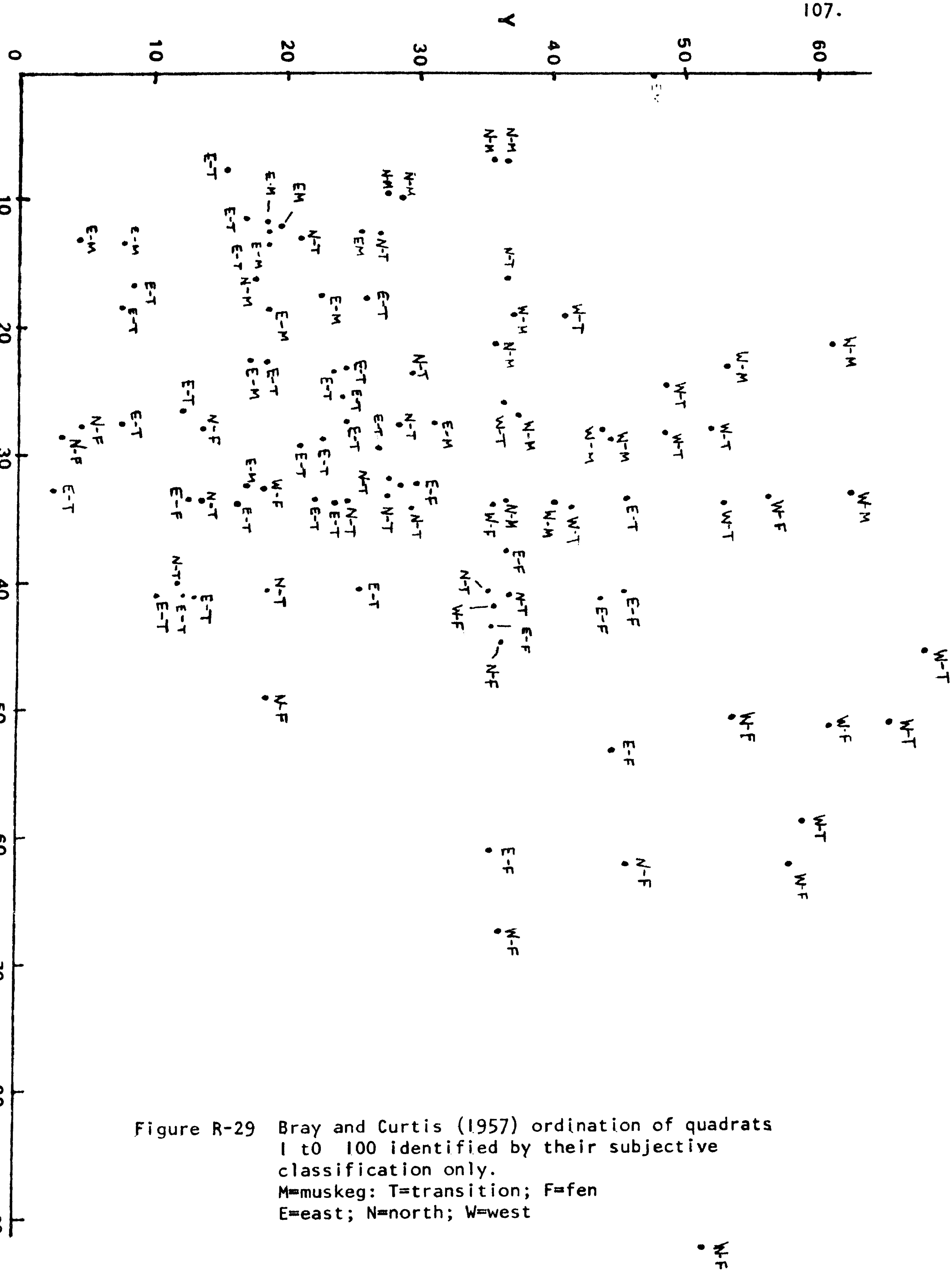


Figure R-29 Bray and Curtis (1957) ordination of quadrats
I t0 100 identified by their subjective
classification only.
M=muskeg: T=transition; F=fen
E=east; N=north; W=west

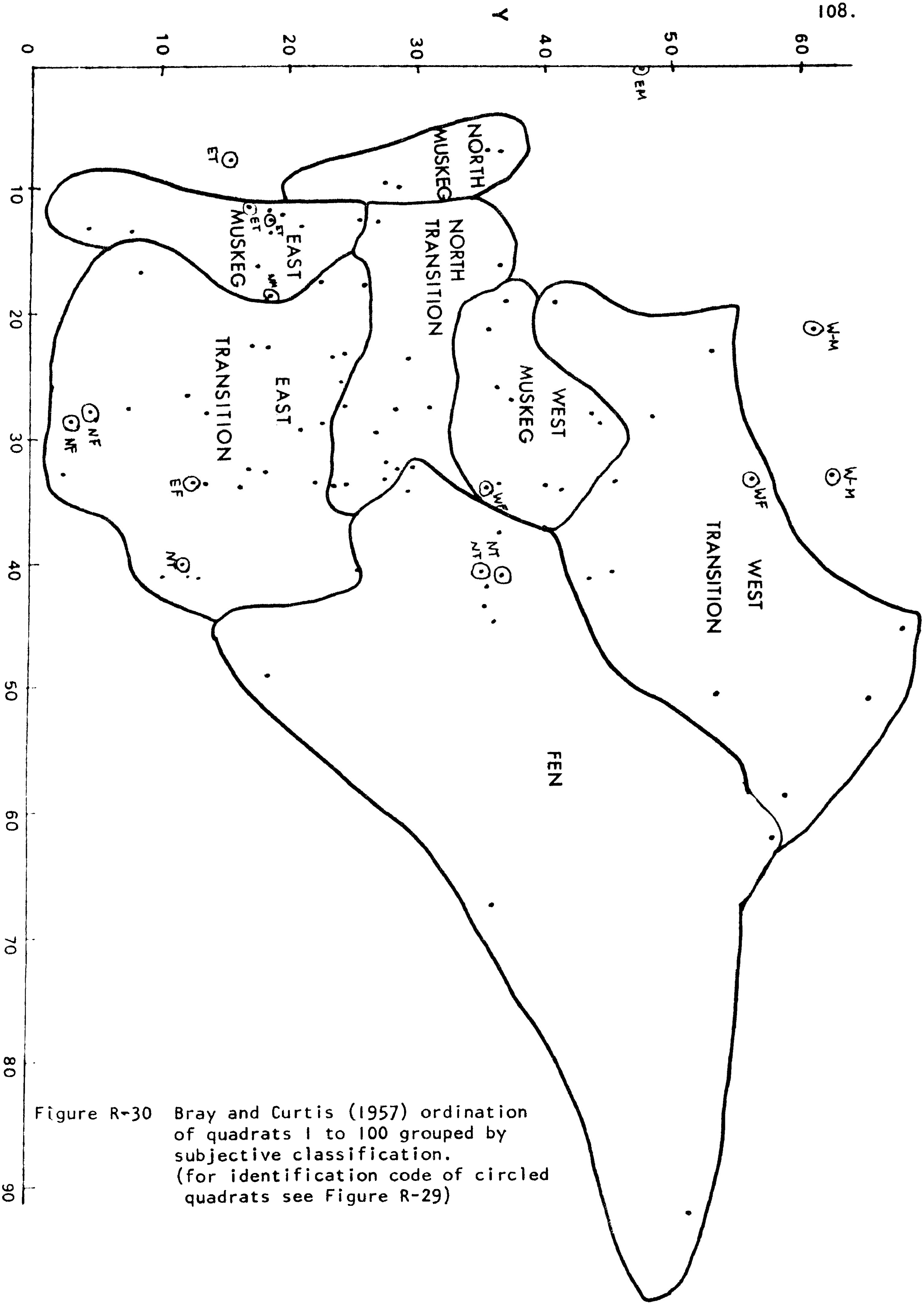


Figure R-30 Bray and Curtis (1957) ordination of quadrats 1 to 100 grouped by subjective classification. (for identification code of circled quadrats see Figure R-29) in a continuous scatter of quadrats which tends toward having a positive slope. East side quadrats were furthest from west side quadrats in the ordination.

(iii) Distribution of frequently occurring species on the Ordination

Distributions of some vascular and bryophyte species were examined on the ordination plot in figures R-31 through R-46. Species were discussed in order of frequency, but, figures were arranged to accommodate discussion of Ericaceous shrubs, and Sphagna. Braun-Blanquet cover values for each species were plotted on the point corresponding to the quadrat, resulting in a scatter of cover values. Optimum habitats were enclosed by isobars.

Figure R-32 is the distribution of cover of *Chamaedaphne calyculata* throughout the ordination. Cover appeared to increase along a gradient from fen to muskeg, highest cover values were generally in the eastern transition zone. *Chamaedaphne calyculata* was present throughout the ordination and occurred in 85% of all quadrats. It was the most commonly recorded species, most vigorous in transition and muskeg sites, and very stunted in fen sites.

Figure R-33 depicts the distribution of Braun-Blanquet cover values of *Vaccinium oxycoccos* within the ordination of quadrats. Cover values were low, although, consistent throughout most quadrats.

Vaccinium oxycoccos occurred in 79% of all quadrats, it was most frequently absent from fen sites. Highest cover was in the eastern transition zone. Plants grew most successfully on *Sphagnum spp.* hummock tops.

Cover values of *Equisetum fluviatile* were plotted on the ordination in Figure R-42. This species was present in 67 per cent of the quadrats and had consistently low cover values in most sites. It was rare in muskeg quadrats, very common in northern and western transitions and exhibited the highest cover values in the fen. *Equisetum fluviatile* grew commonly in the hollows between *Sphagnum spp.* hummocks or with the many *Carex* species common to the fen.

Figure R-35 depicts the cover of *Andromeda glaucophylla* in the 58 quadrats where it was recorded. Its highest cover was in the eastern and western transition zones. *Andromeda glaucophylla* was common to wetter sites within the transition and was found closer to the fen than *Chamaedaphne calyculata.*

Kalmia polifolia occurred in 51% of the quadrats sampled. Figure R-34 illustrates Braun-Blanquet cover values recorded on the ordination for this species. *Kalmia polifolia* was most common in transition sites, although, with fairly low cover. Highest cover values were found in the eastern transition zone. It was very rare in fen sites. *Kalmia polifolia* tends to occupy drier *Sphagnum spp.* hummocks and was often found with *Chamaedaphne calyculata.*

Figure R-43 illustrates the cover of *Carex limosa* in the ordination of quadrats. It occurred in 43% of the quadrats and was the most commonly occurring *Carex* species in the study area. Its habitat preference was broad; highest cover values were in the eastern and northern transition zones. Its cover in muskeg was about the same as its cover in fen, although, it occurred more frequently in the fen.

Smilacia trifolia occurred in 41% of the quadrats. Its cover values were plotted on the ordinated quadrats in Figure R-45. It was absent in the fen and rare in the western transition zone. Highest cover values were found in the eastern transition zone. It was common in muskeg sites as well. *Smilacina trifolia* was often found on the tops and sides of well developed *Sphagnum spp.* hummocks.

Figure R-46 illustrates the cover values of *Picea mariana* in ordinated quadrats. It was present in 36% of the quadrats and exhibits highest cover values in muskeg sites. *Picea mariana* was common in the transition zones as well. Some high cover values in transition sites were due to dense patches of *Picea mariana* which flourish on the tops of *Sphagnum spp.* hummocks. Although cover was great in this situation the trees were much shorter and frequently more contorted than muskeg specimens.

Figure R-31 depicts the cover of *Ledum groenlandicum* in ordinated quadrats. It occurred in 35% of the quadrats and exhibited highest cover values in west side muskeg sites. *Ledum groenlandicum* was most common in muskeg and transition and was rare in the fen. It tends to occupy the tops and sides of well developed *Sphagnum spp.* hummocks.

Figure R-41 illustrates the cover of *Menyanthes trifoliata* in quadrats. It grew predominently in wet sites, usually in the fen or wet hollows in the transition zones. Both *Eriophorum spissum* and *Utricularia radiata* grew exclusively in the fen and very wettest transition sites (see Figures R-39 and R-40). *Eriophorum spissum* grew in patches on the floating portion of the fen while *Utricularia radiata* grew singly in hollows or patches of open water.

The cover of four bryophyte species who were present in at least 30% of the quadrats sampled was applied to the ordination in Figures R-36 through R-38 and R-44.

Sphagnum magellanicum occurred in 64% of the quadrats. Its Braun-Blanquet cover values were plotted on the ordination in Figure R-36. Its highest cover values occurred in the fen, especially in plots ordinated close to transition plots. *Sphagnum magellanicum* was common to wet transition sites, or hollows in dry transition sites. It formed large, loose moist hummocks in wetter sites or occupied the sides of well developed hummocks in drier sites.

Cover of *Sphagnum fuscum* is plotted in Figure R-38. It occurred in 58% of the quadrats sampled and achieved its highest cover in eastern transition and muskeg sites. *Sphagnum fuscum* was common to the tops of well developed hummocks in moist or dry sites. It capped these hummocks with dense growth which was well elevated and frequently much drier than a *Sphagnum magellanicum* hummock of equivalent size.

Figure R-37 depicts the Braun-Blanquet cover values achieved by *Sphagnum recurvum*, which was present in 52% of the quadrats sampled. It was common to transition zone sites, especially northern and western locations. It rarely formed hummocks but, often occupied the tops of moist *Sphagnum magellanicum* hummocks or the upper sides of *S. fuscum* hummocks. Occasionally *S. recurvum* did produce a small secondary hummock on the moist edge of a well developed hummock. *S. recurvum* was also common just above the water line in hollows. In this location varieties of *S. recurvum*, such as *S. recurvum var tenue* and *S. recurvum var brevifolium* were often encountered.

Figure R-44 depicts the cover values of *Polytrichum juniperinum var affine* plotted on the ordination of quadrats. It occurred in 39% of the quadrats and was restricted almost exclusively to eastern transition zone and muskeg sites. *Polytrichum juniperinum var affine* grew on the dry tops of *Sphagnum fuscum* capped hummocks often in association with *Vaccinium oxycoccos*. It appeared to be intolerant of moister conditions and was rare in wet transition or fen sites.

Figures R-31 through R-46 inclusive

Braun-Blanquet cover values of twelve vascular and four bryophyte species plotted on the Bray and Curtis (1957) ordination of quadrats 1 to 100. Species are arranged in an order that facilitates their discussion in the text of the discussion section.

Ledum groenlandicum

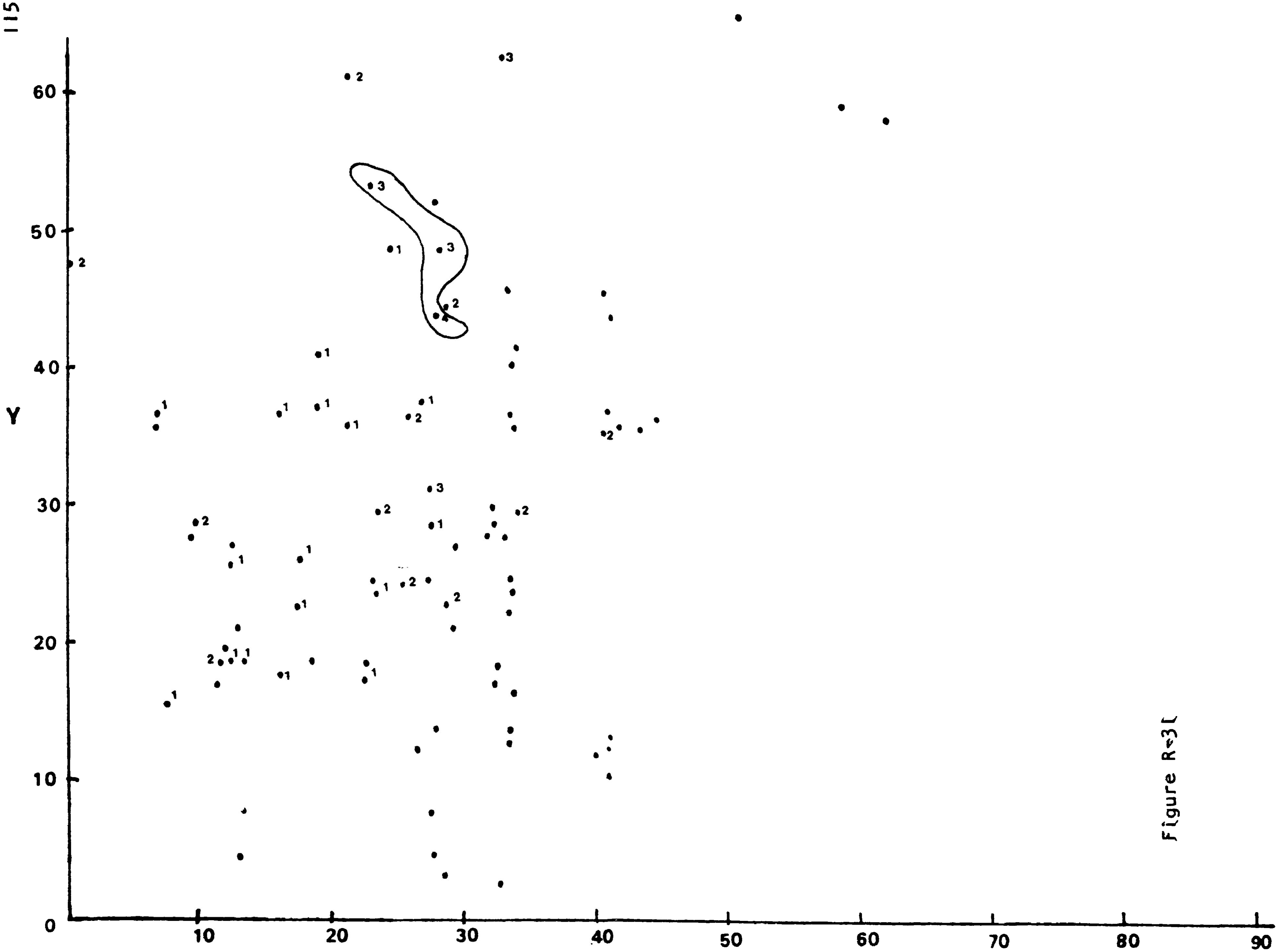


Figure R-3(

Chamaedaphne calyculata

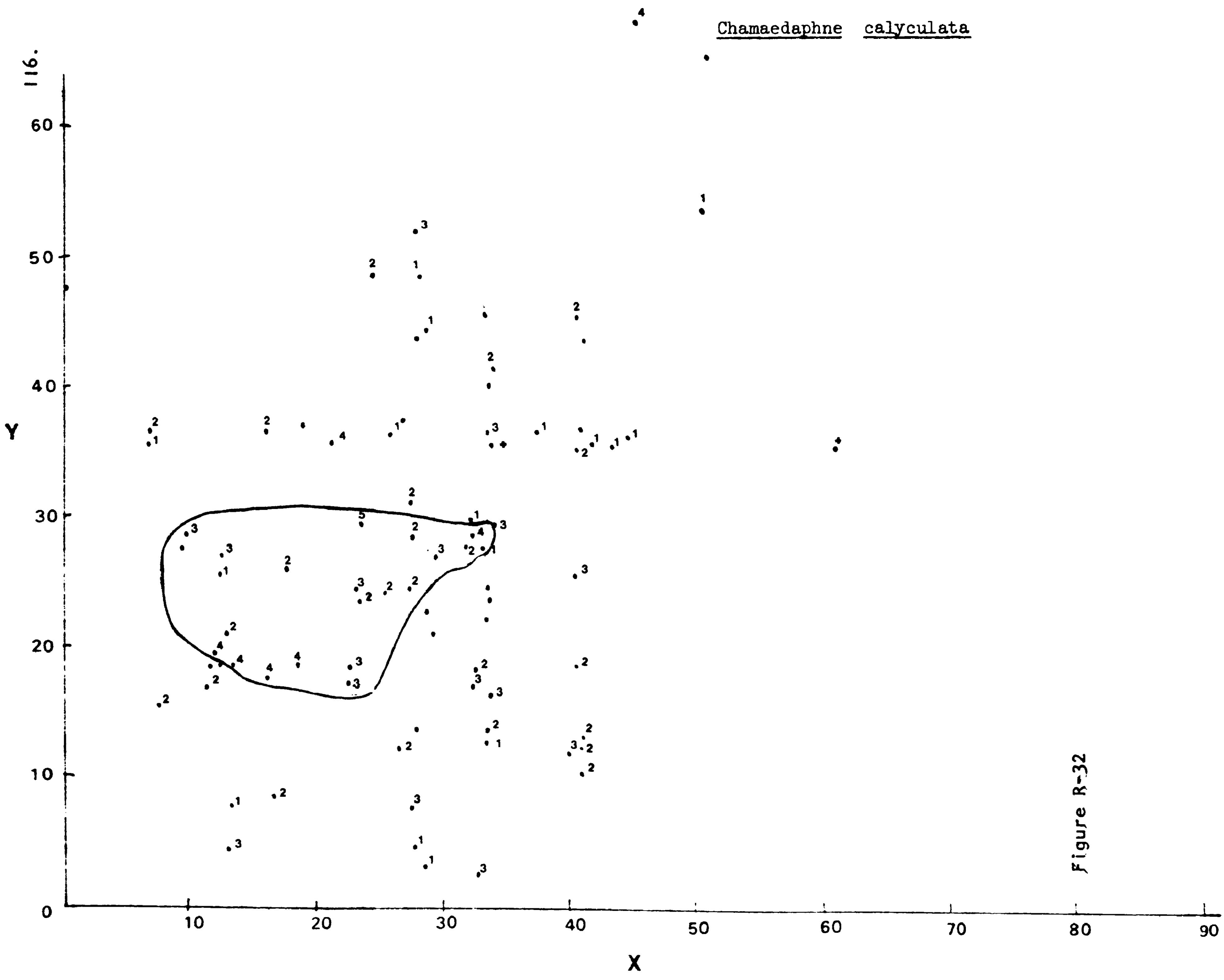


Figure R-32

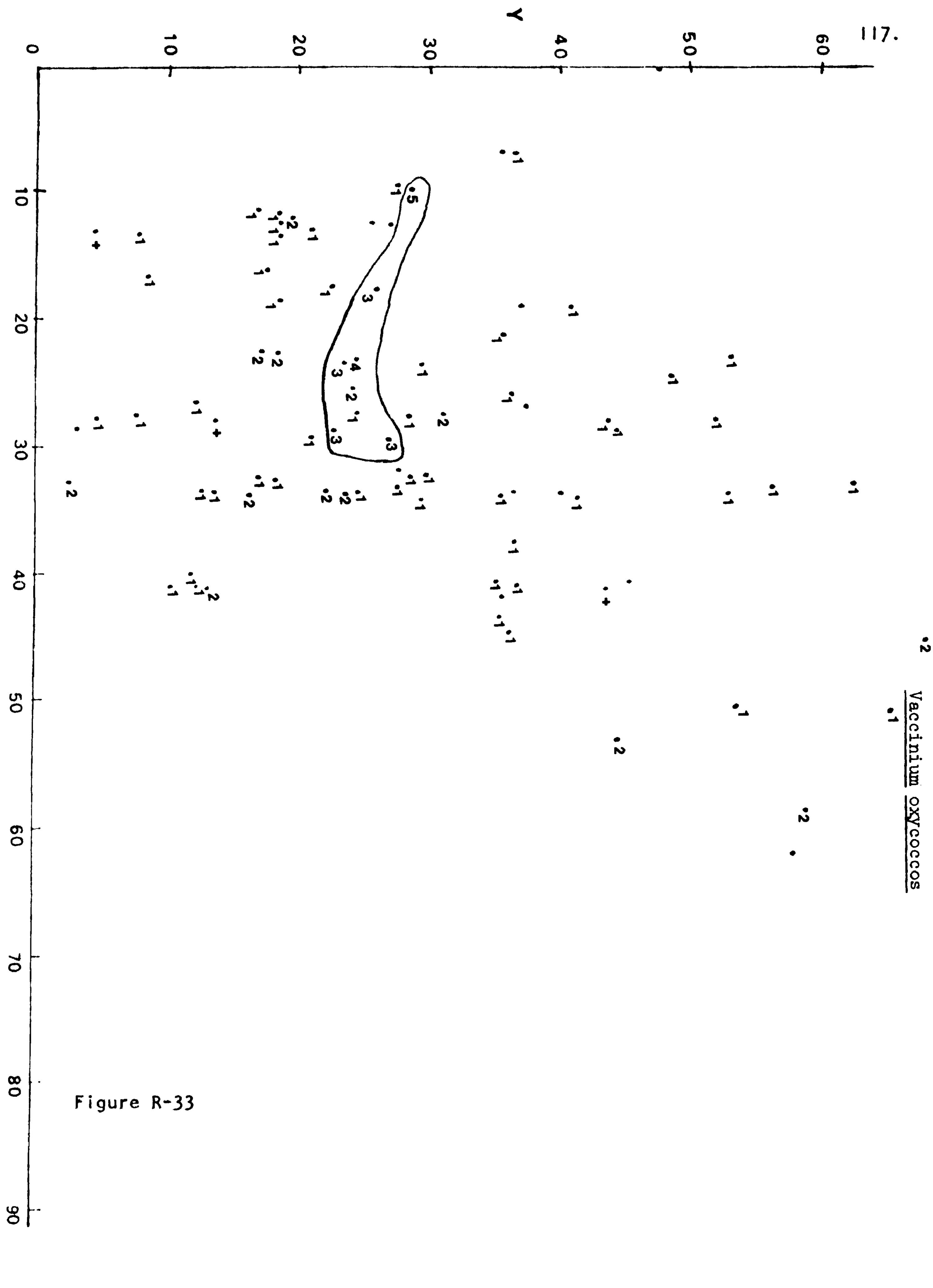


Figure R-33

Kalmia polifolia

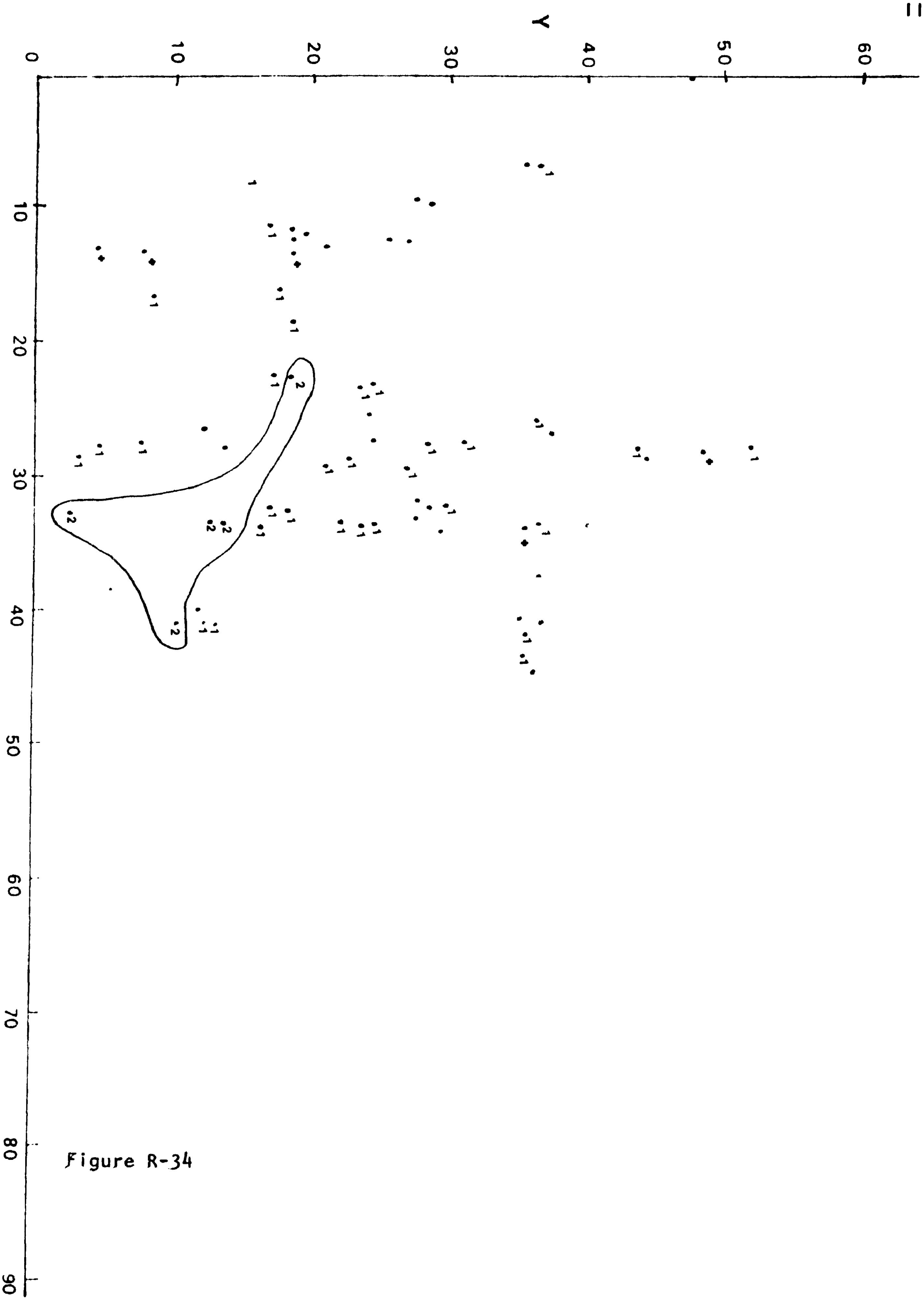


Figure R-34

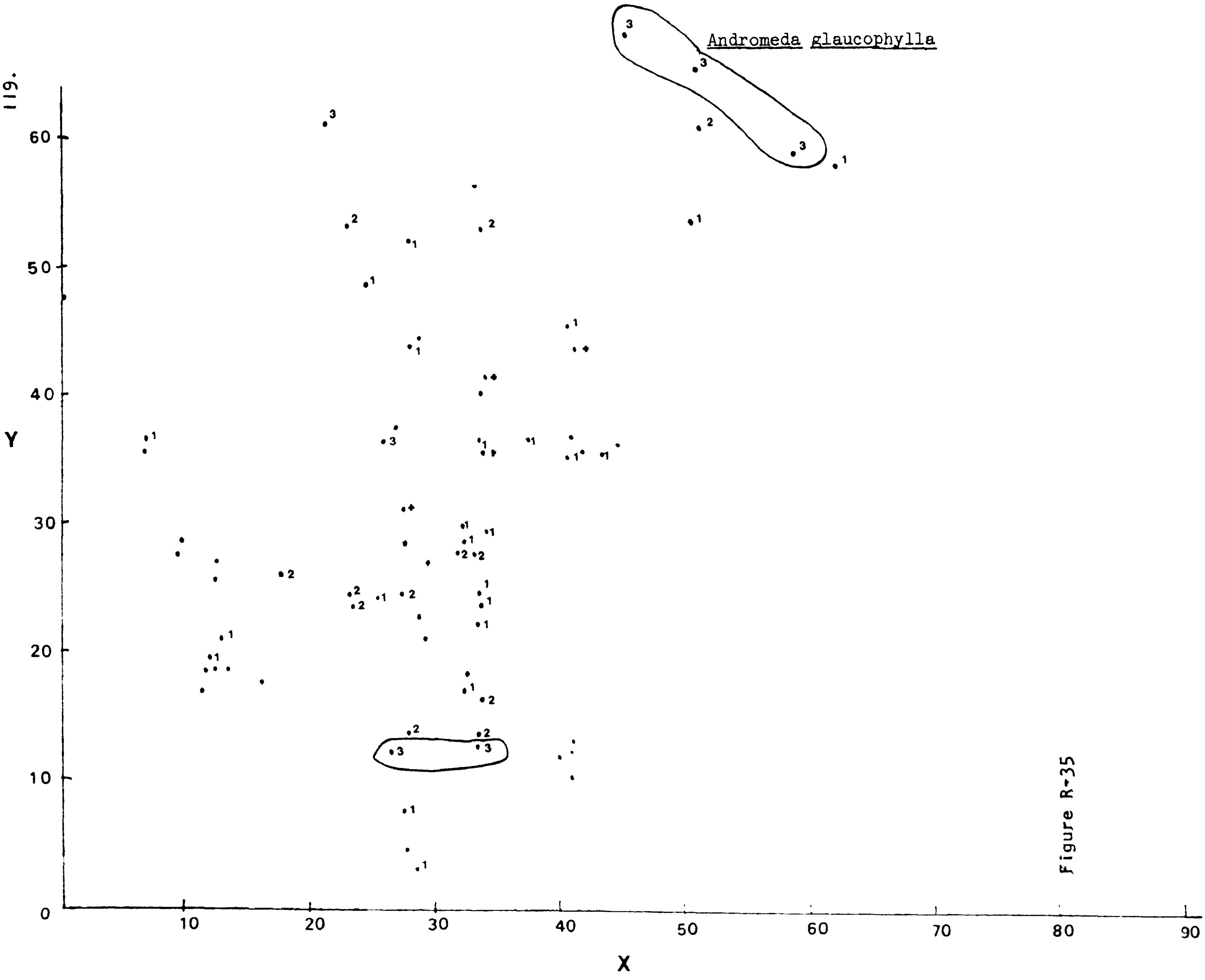


Figure R-35

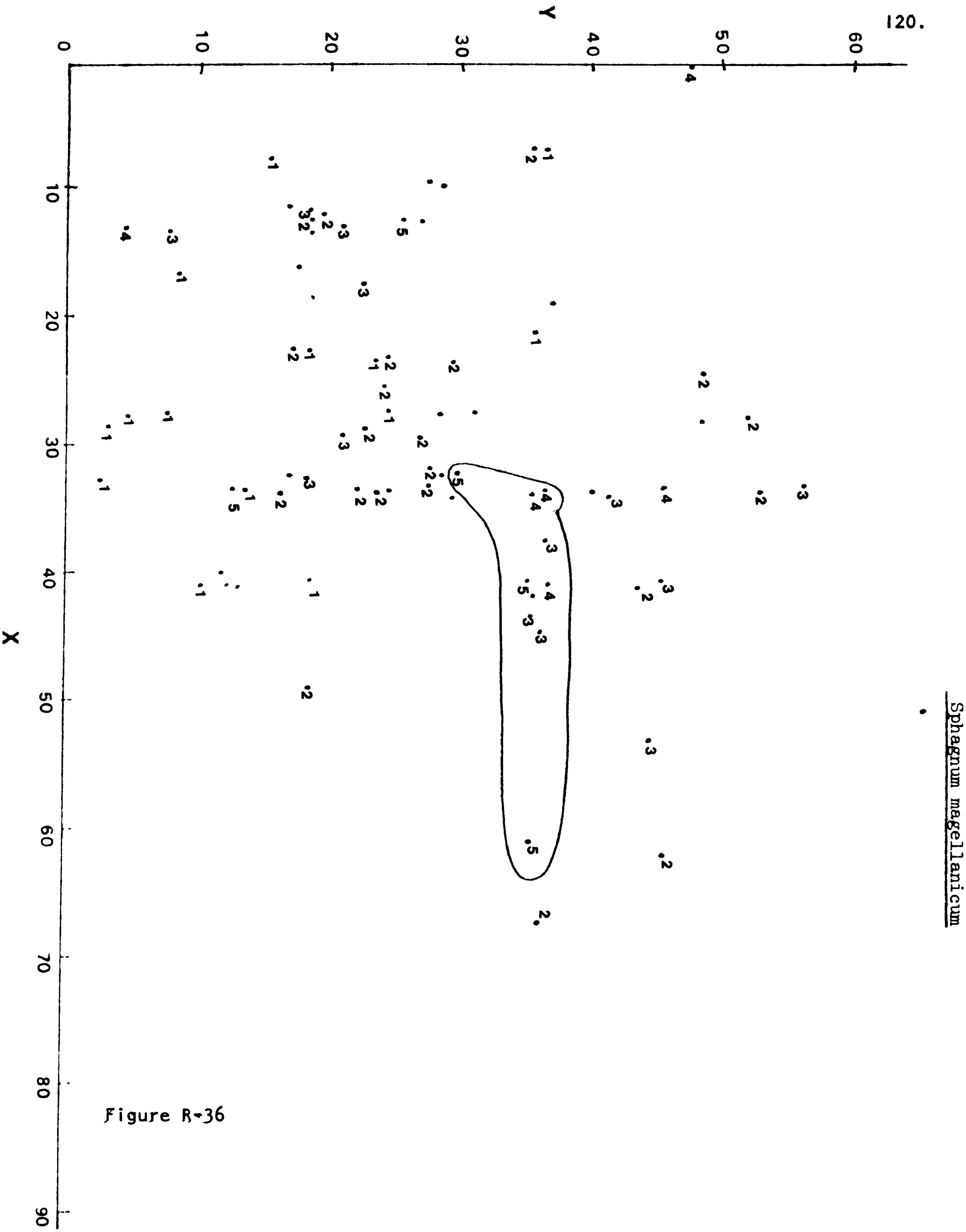


Figure R-36

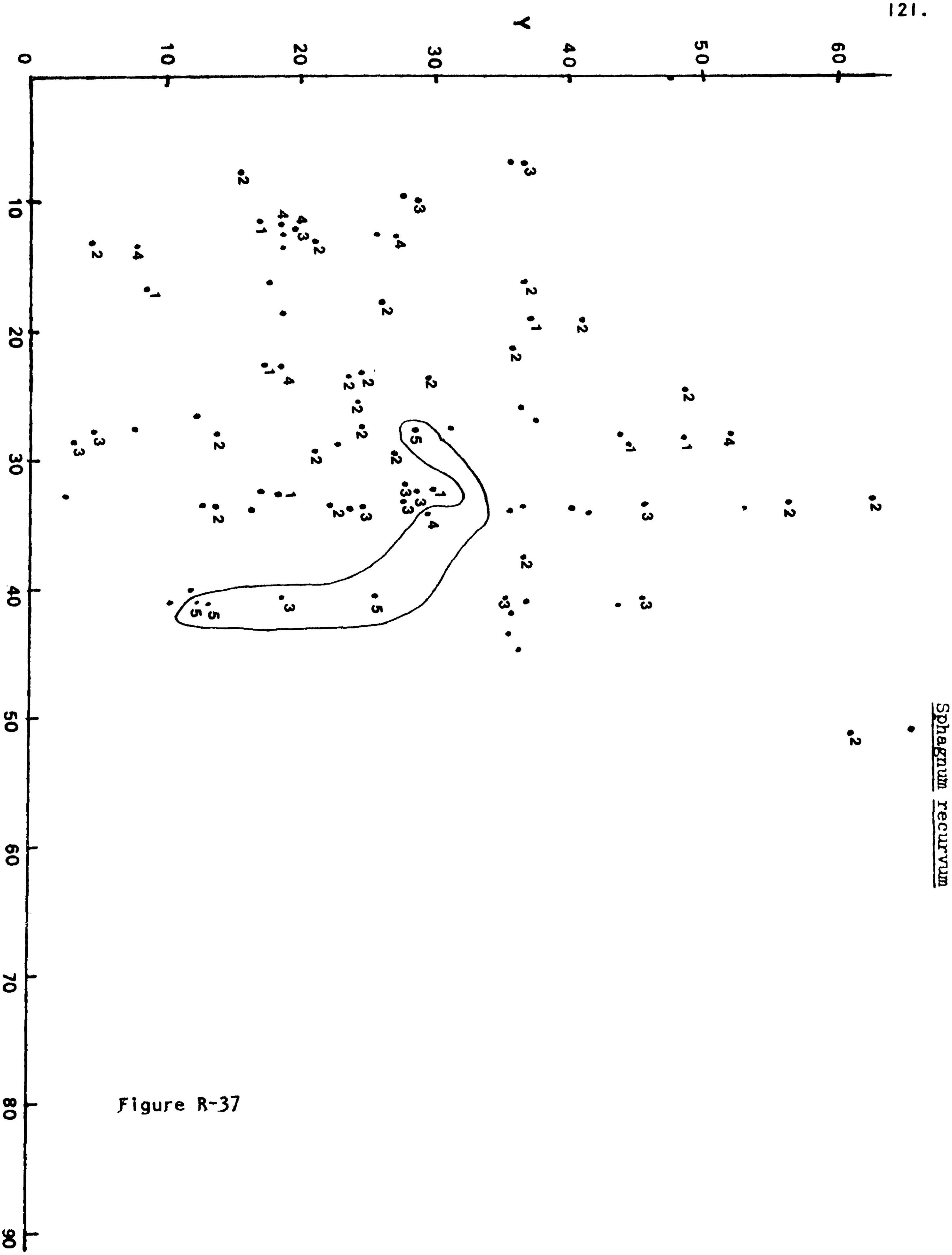


Figure R-37

Sphagnum fuscum

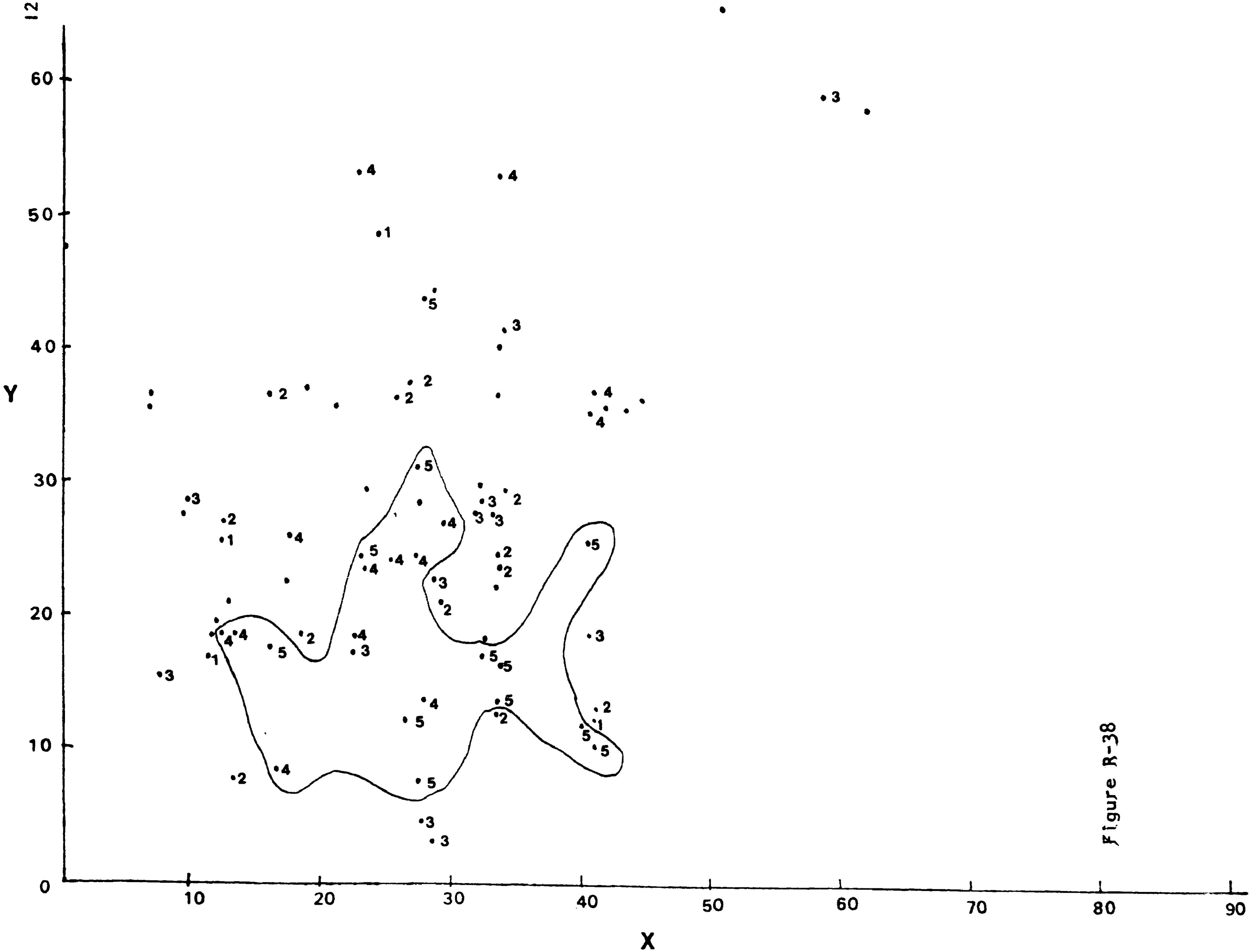


Figure R-38

<u>Eriophorum</u> <u>spissum</u>

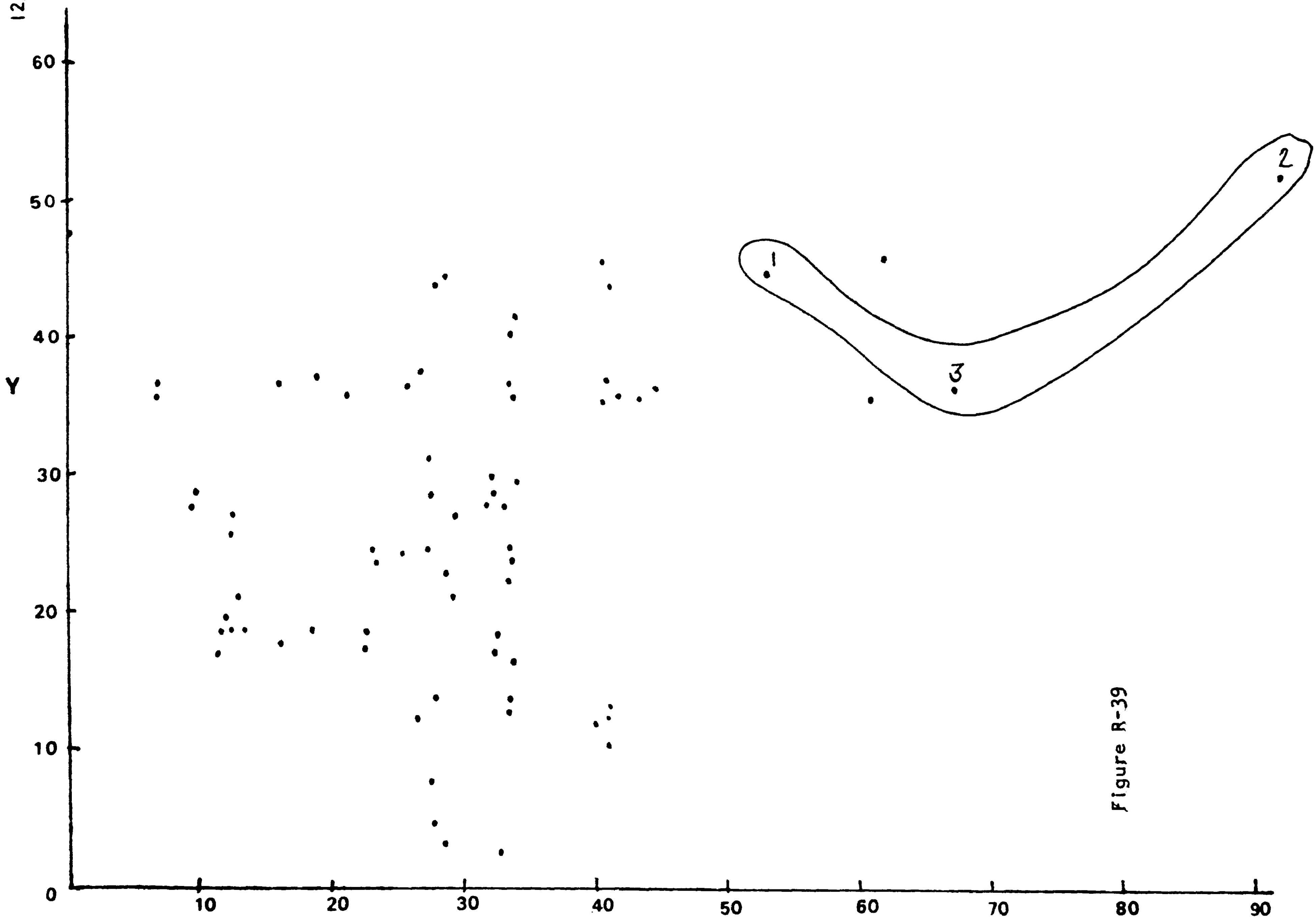


Figure R-39

Utricularia radiata

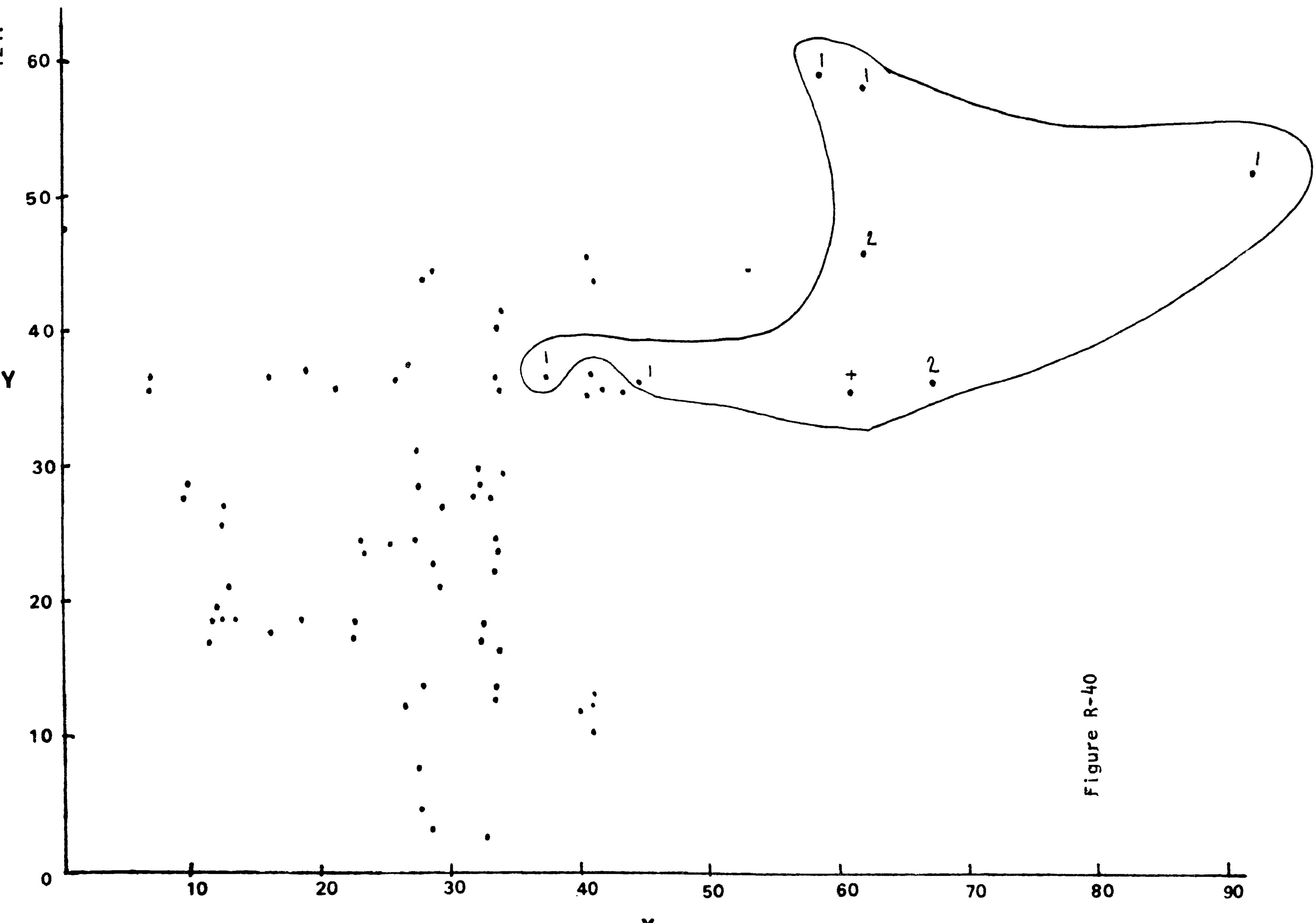


Figure R-40

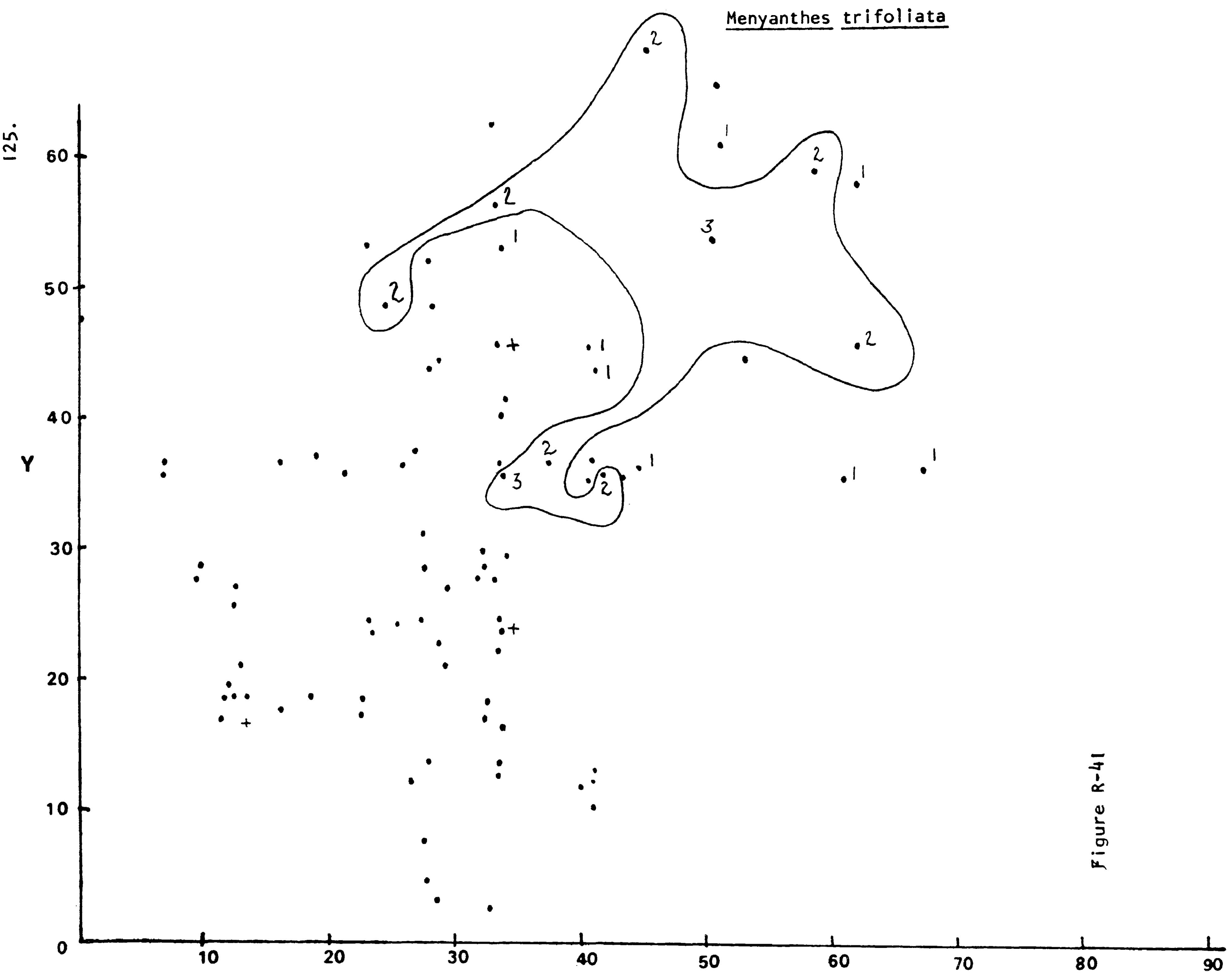


Figure R-41

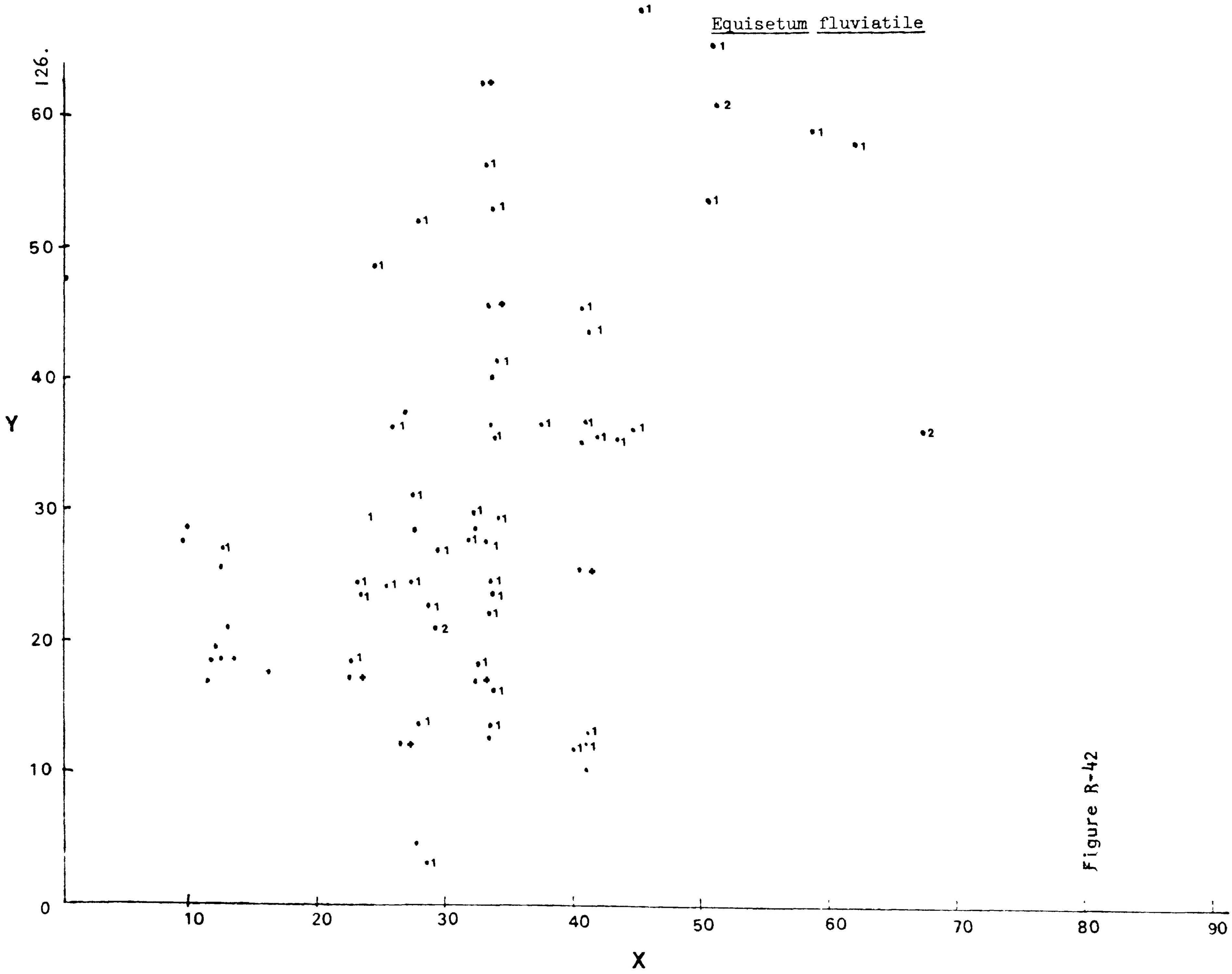


Figure R-42

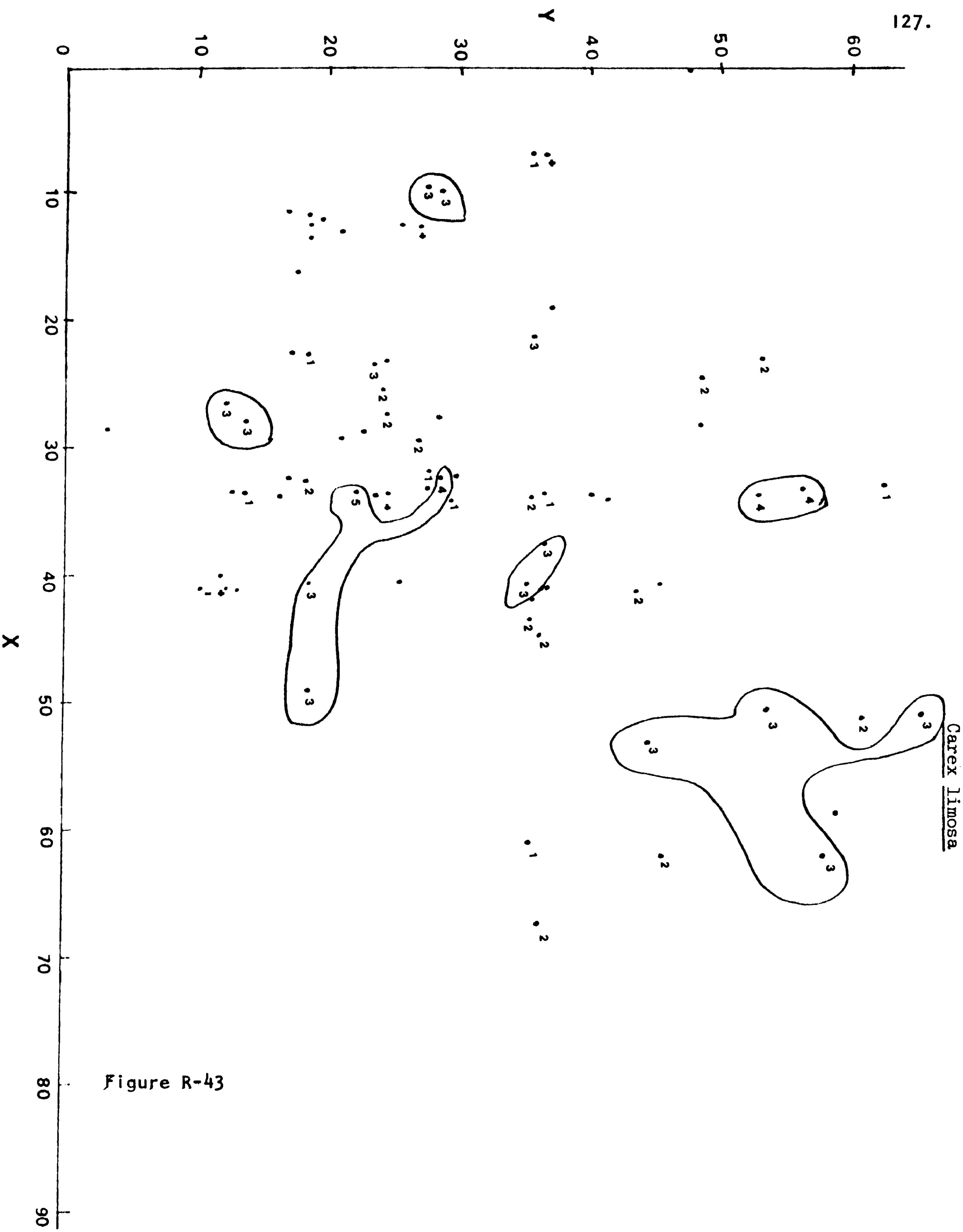


Figure R-43

Polytrichum juniperinum var. *affine*

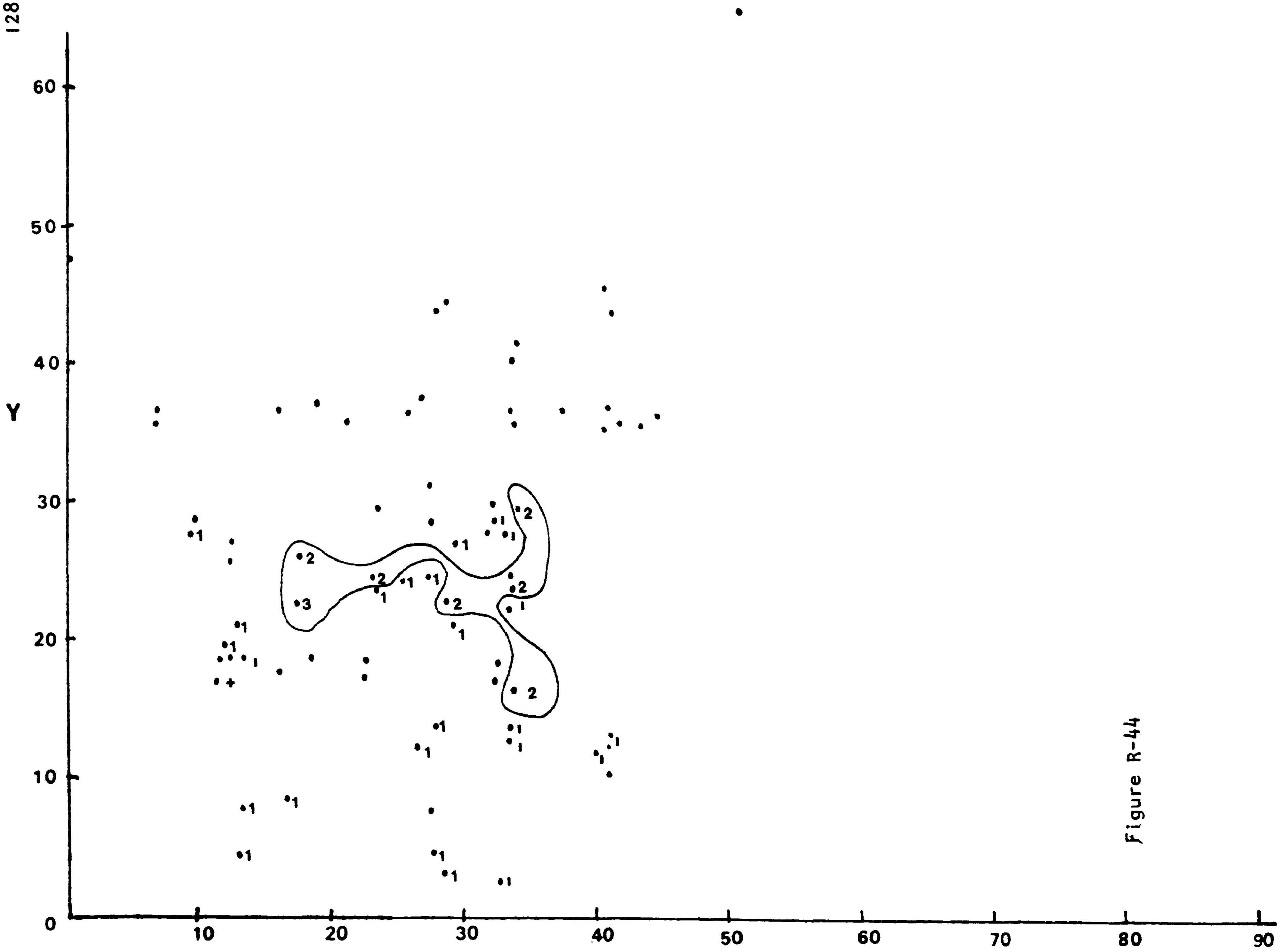


Figure R-44

Smilacina trifolia

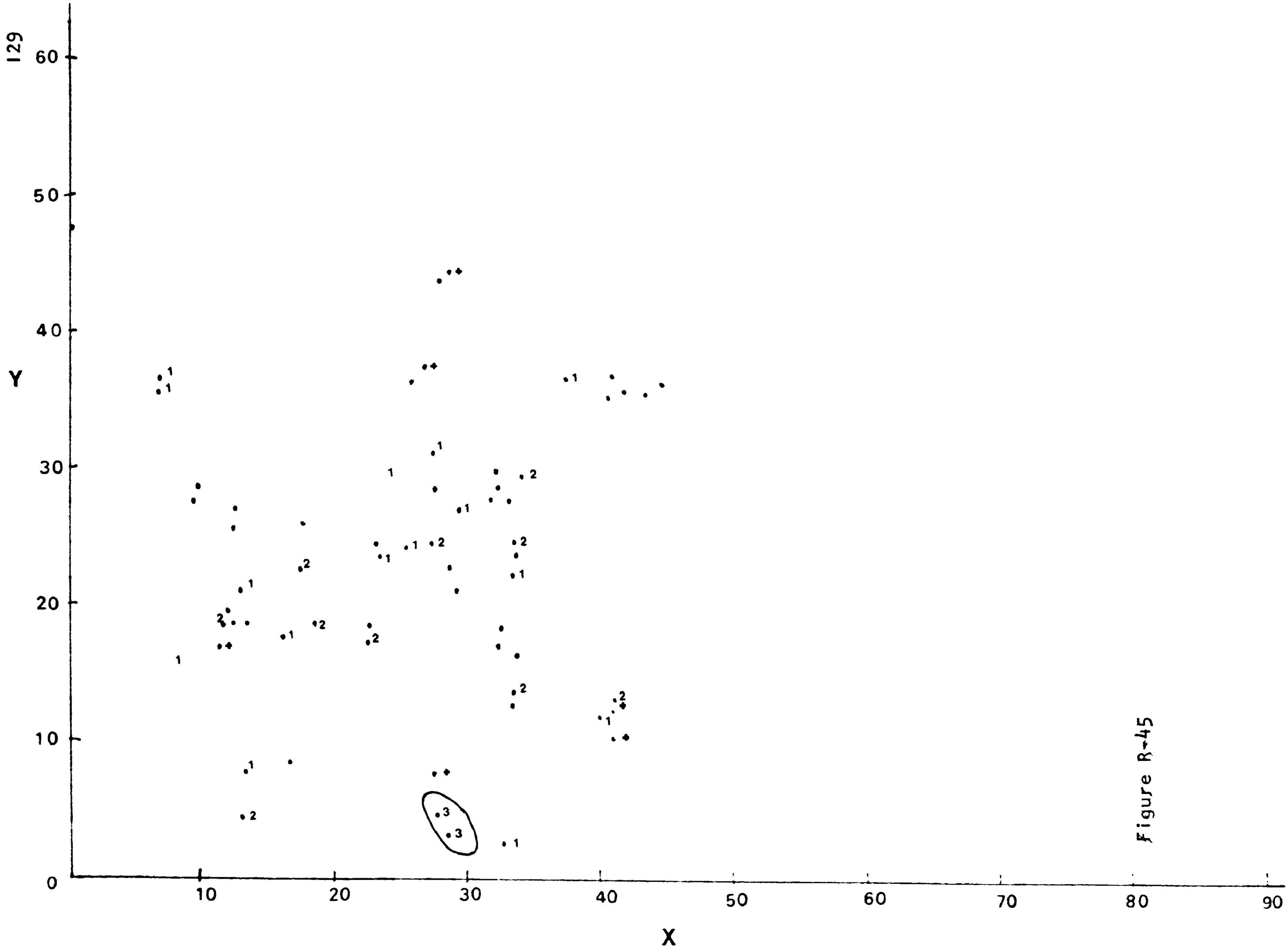


Figure R-45

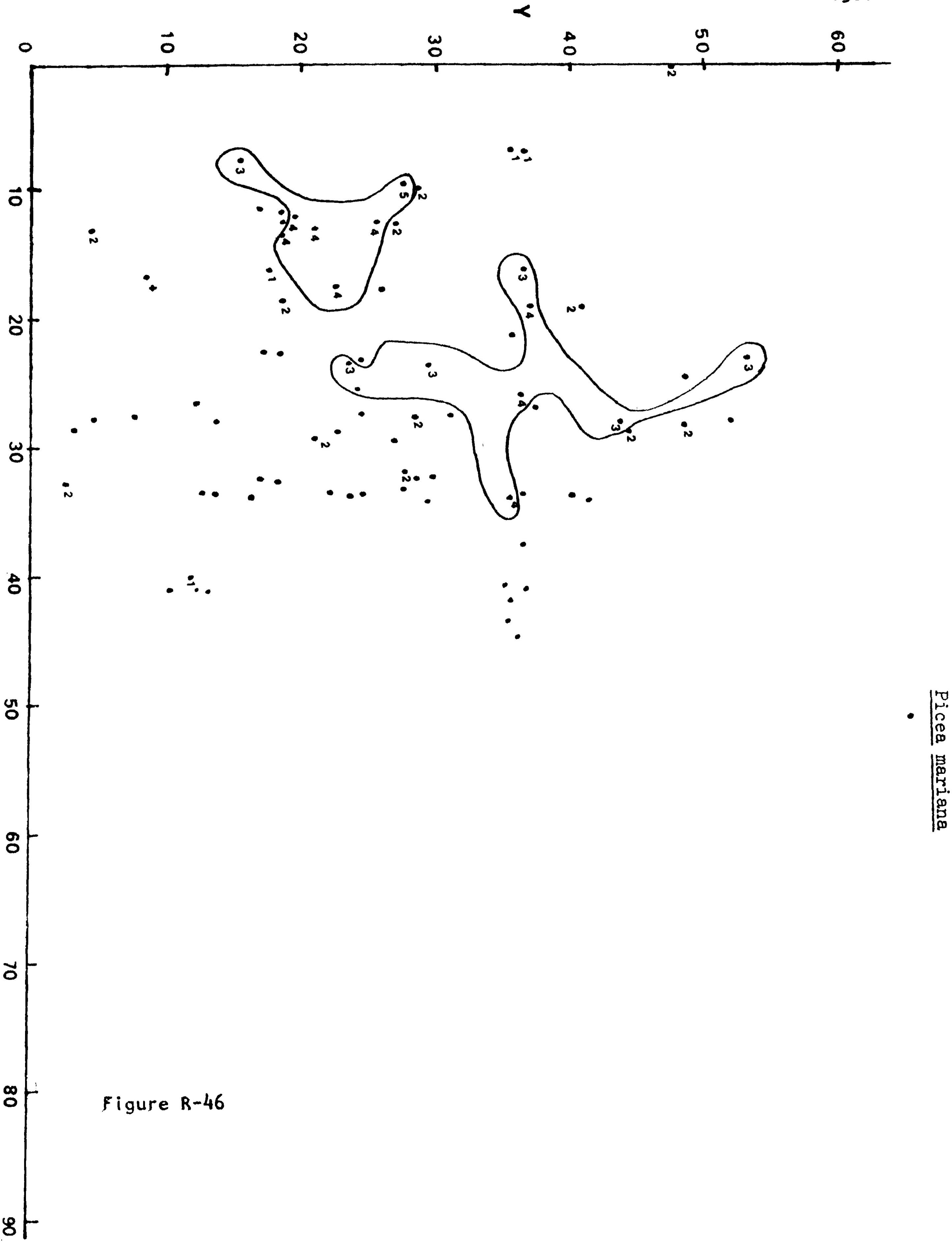


Figure R-46

f) Normal Association Analysis of Quadrats 1-100

A Williams and Lambert Normal Association Analysis was undertaken upon presence-absence data from quadrats 1-100 (see Methods). Chi-square cut off was dictated to be 1.00, although, in one group subdivisions were made at chi-square values below one.

Figure R-47 is a dendritic diagram of the normal association analysis. Group formation was poor at high chi-square values, consequently, this analysis was only 95% reliable (see Greig-Smith 1964 p. 169). However, groups that were formed are ecologically recognizable and correspond favourably with field observations.

Three major groups of quadrats were sorted in this analysis. The first split was based on the presence of *Picea mariana*. Within the 36 quadrats containing *Picea mariana* a second division was made based on the presence of *Chamaedaphne calyculata*. The 30 quadrats which contain both *Picea mariana* and *Chamaedaphne calyculata* form the group A. Of the 64 quadrats which do not have *Picea mariana*, 26 were separated on the basis of *Polytrichum juniperinum var affine*. These twenty-six quadrats comprise group B. The remaining 38 quadrats were subdivided on the presence of *Equisetum fluviatile*. The 36 quadrats in which it occurred make up group C of the Normal Association Analysis. Within group C 29 quadrats contained *Chamaedaphne calyculata* and of these 9 contained *Sphagnum fuscum*, these nine quadrats made up group C-1. The 17 remaining quadrats which contained *Equisetum fluviatile* and *Chamaedaphne calyculata* only are group C-2. Finally the seven quadrats which contained *Equisetum fluviatile* only compose group C-3. Table R-49 outlines quadrats which were not sorted into a normal group A, B or C and quadrats not included in the analysis in addition to listing quadrats present in each Normal group. These quadrats are marked on Figures R-50 and R-51.

Continued on page 136.

Figure R-47 Dendritic diagram illustrating the results of a Williams and Lambert Normal Association Analysis (Williams and Lambert 1959) of floristic presence/absence data from quadrats 1 to 100. Chi-square cut off 1.00.

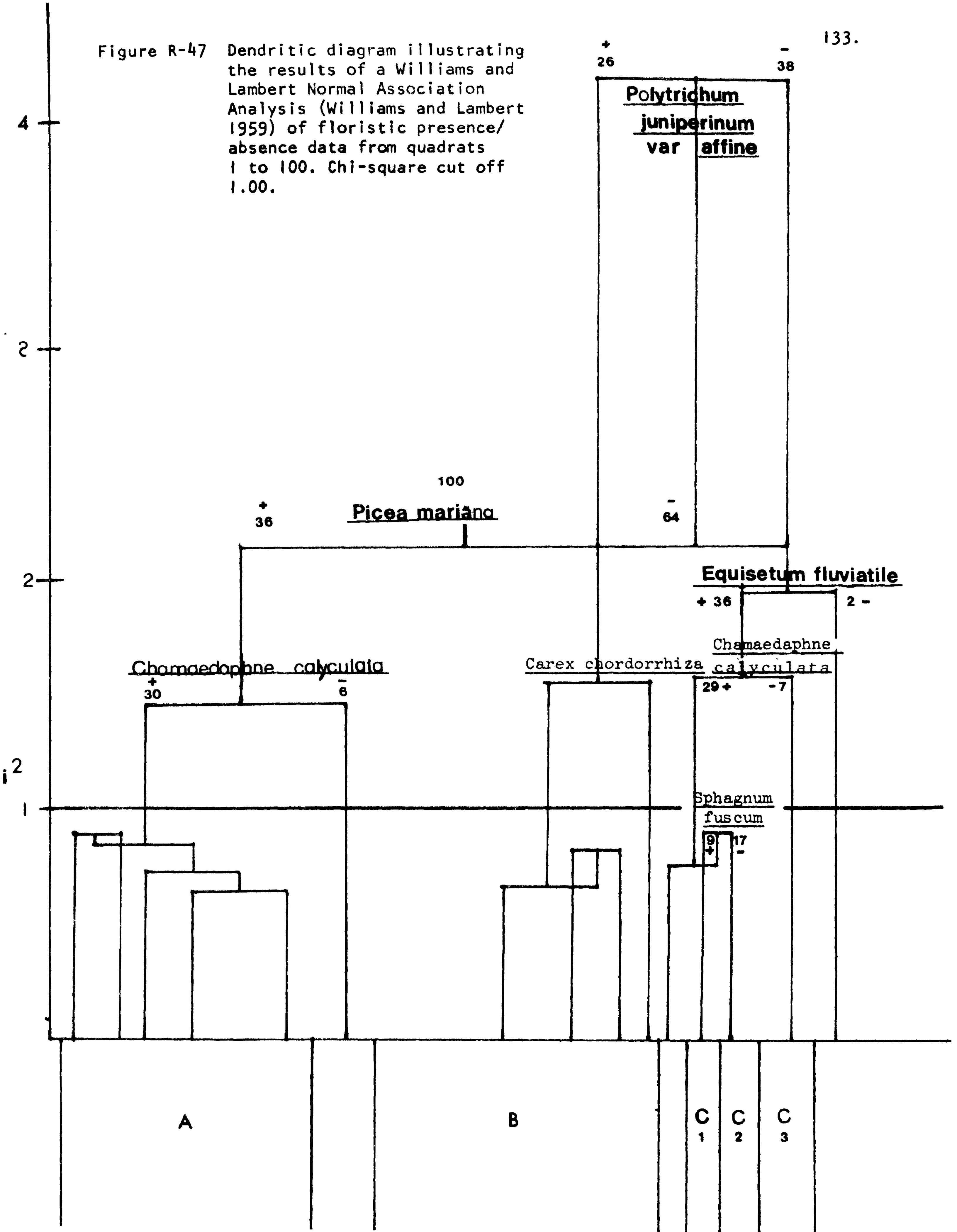


Table R-48

NORMAL ASSOCIATION ANALYSIS OF QUADRATS 1 - 100

GROUP	DETERMINANT SPECIES
A	Picea mariana - Chamaedaphne calyculata
B	Polytrichum juniperinum var affine
C-1	Equisetum fluviatile - Chamaedaphne calyculata Sphagnum fuscum
C-2	Equisetum fluviatile - Chamaedaphne calyculata
C-3	Equisetum fluviatile

Table R-49 Quadrats present in Normal groups and eliminated from Normal Analysis

Normal group	Quadrats
A	1, 5, 18, 20, 23, 31, 32, 34, 37, 39, 53, 54, 62, 66, 67, 4, 9, 19, 22, 33, 36, 48, 49, 50, 51, 52, 90, 99.
B	55, 58, 95, 98, 29, 40, 61, 91, 94, 97, 100, 3, 10, 2, 7, 8, 11, 17, 25, 26, 38, 44.
C-1	6, 21, 24, 35, 41, 43, 68, 83, 85
C-2	12, 13, 14, 15, 27, 28, 30, 45, 46, 47, 60, 71, 72, 73, 74, 75, 96.
C-3	42, 81, 84, 86, 87, 88, 89.

Quadrats not included in Normal groups - circled on ordination

16, 63, 64, 65, 78, 79

69, 70, 82

76

- these quadrats formed small groups at chi-square values less than 1.00 and were remote from their higher level group on the Bray and Curtis ordination. (note that they are frequently west side quadrats)

Quadrats excluded from analysis - X on ordination

-misclassified in analysis (first computer run)

77, 80, 92, 93

Groups A, B and C represent an ecological series within the study area which are easily identifiable. Group A represented muskeg sites or dry transition sites with a well developed *Chamaedaphne calyculata* understorey and a *Picea mariana* overstorey. Group B can be interpreted as hummock tops in the dry transition zone where a coniferous overstorey was absent. Group C contained a large number of quadrats in which *Equisetum fluviatile* was present. It was subdivided into group C-1 which consisted of quadrats which fall into transition zone sites which include dry *Sphagnum fuscum-Chamaedaphne calyculata* on the hummock tops and *Equisetum fluviatile* in the hollows. C-1 quadrats were slightly wetter than B quadrats. Quadrats grouped under C-2 were moister than C-1 quadrats and lack *Sphagnum fuscum* hummocks. C-2 quadrats were located in intermediately wet transition zone sites. C-3 quadrats were classified on the basis of the presence of *Equisetum fluviatile* alone. These quadrats fall into very wet transition zone and fen sites.

Quadrat groups identified by the Normal Association analysis were plotted onto the ordination of quadrats in Figure R-50. Groups go from dry to wet along the X ordination axis. Figure R-51 summarizes the Normal groups on the ordination by their location and physiognomy.

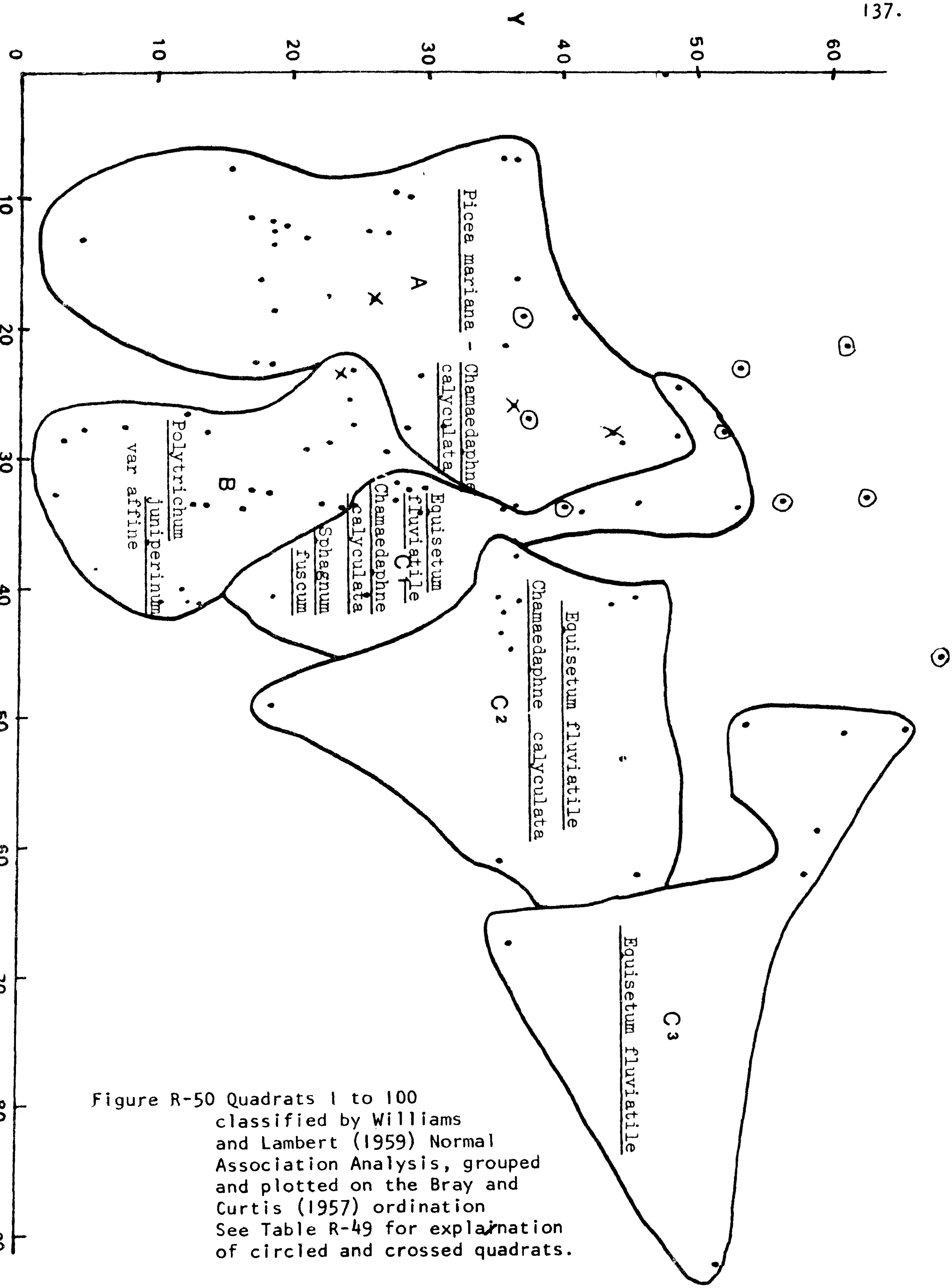


Figure R-50 Quadrats 1 to 100 classified by Williams and Lambert (1959) Normal Association Analysis, grouped and plotted on the Bray and Curtis (1957) ordination See Table R-49 for explaination of circled and crossed quadrats.

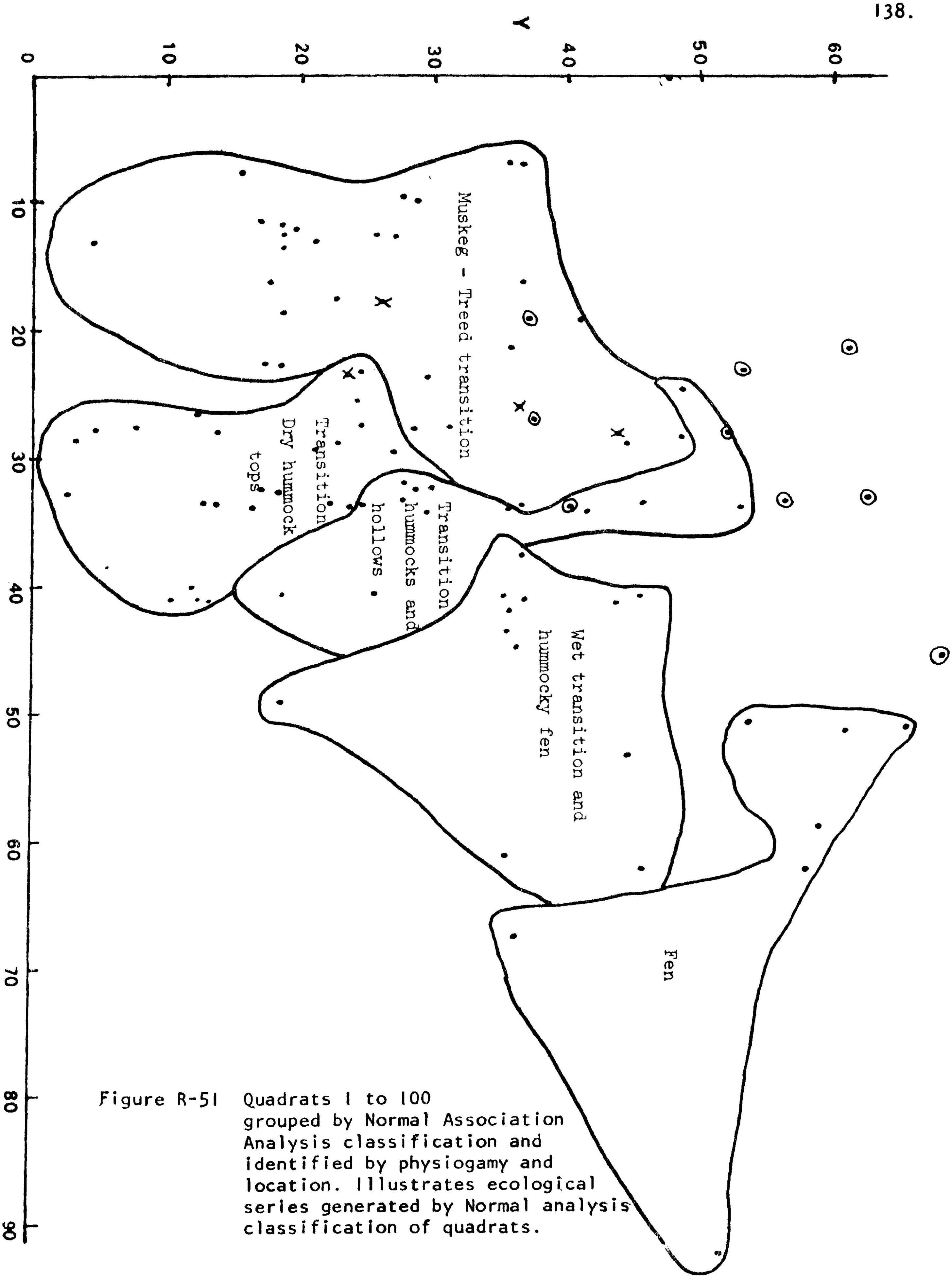


Figure R-51 Quadrats 1 to 100 grouped by Normal Association Analysis classification and identified by physiogamy and location. Illustrates ecological series generated by Normal analysis classification of quadrats.

g) Principal components analysis based upon floristic data only

A Principal Components analysis was undertaken upon presence-absence vegetation data from 74 quadrats* from transects B through F. Quadrats were plotted between the first two axes of quadrat component scores (see Methods III-C(ii)) in Figure R-52. Component scores were based entirely upon floristic data.

Quadrats appeared to be widely scattered between the axes with no distinct clumping into groups. Points followed a curve which ran from high axis one, low axis two values, through high one and two values to low one and two values (see Figure R-52).

Quadrats subjectively classified as muskeg, transition or fen, and by location in relation to fen centre, were plotted on the ordination resulting from Principal Components analysis. Quadrats falling within the same classification type were enclosed in groups of quadrats (see Figure R-53). 7% of the quadrats (5) could not be included in their group because their component scores placed them too far away from the majority of quadrats in the group.

Fen, west and north transition quadrats were closely associated at the bottom of the ordination along axis 2. Eastern transition, northern muskeg and three northern transition quadrats were placed in the midregions of the ordination. Eastern muskeg quadrats were located in the upper right region of the ordination and western muskeg quadrats in the upper left.

---

* P.C.A. program parameters allowed analysis of 75 samples per run.

Figure R-54 illustrates quadrats falling into groups delimited by Normal Association analysis. 17% of the quadrats plotted on the ordination were remote from their Normal groups. Dotted lines enclose quadrats which belong to adjacent groups, but, fall between quadrats belonging to another group. There was a trend from muskeg to fen which followed the same curve as outlined in Figure R-52. Wet transition (C2) and fen (C3) plots occupied very similar locations in the diagram.

When comparing the results of Bray and Curtis Ordination to Principal Components analysis (P.C.A.) ordination (axes 1 and 2 only) it was found that the spatial location of Normal groups was very similar in both ordinations when the P.C.A. ordination was inverted and rotated 90° to the left (Figure R-55). Differing methods of axis derivation resulted in two ordinations, both entirely based upon floristic data, which were similar in the way they sort the quadrat data.

Correlation coefficients (r) were calculated between the 38 vascular and bryophyte species used in the Principal Components analysis and the first two component axes. Results are presented in Table R-56.

Species positively correlated with axis 1 at the 0.05 level of significance were *Picea mariana* and *Ledum groenlandicum*. As axis 1 component scores increased so do the frequencies of these two species in quadrats located along axis 1. *Andromeda glaucophylla* and *Equisetum fluviatile* were negatively correlated with axis 1. Frequencies of these species decreased in quadrats located along axis 1.

Species positively correlated ($P \leq 0.05$) with axis 2 were *Polytrichum juniperinum var affine*, *Sphagnum fuscum* and *Smilacina trifolia*. Frequencies of these species increased in quadrats located along axis 2. There were no species significantly negatively correlated with axis 2.

Table R-56 includes the percentage of total variance accounted for by each species. *Sphagnum fuscum* and *Carex limosa* had the highest per cent variance (4.616%) of all the species used in the analyses.

The proportion of total variance accounted for by axis 1 was 0.155 and axis 2 is 0.114. The greater proportion of variation in the Principal Components analysis could not be accounted for by the axes constructed from entirely floristic data. Factors other than floristics were responsible for a large proportion of the variance within the data.

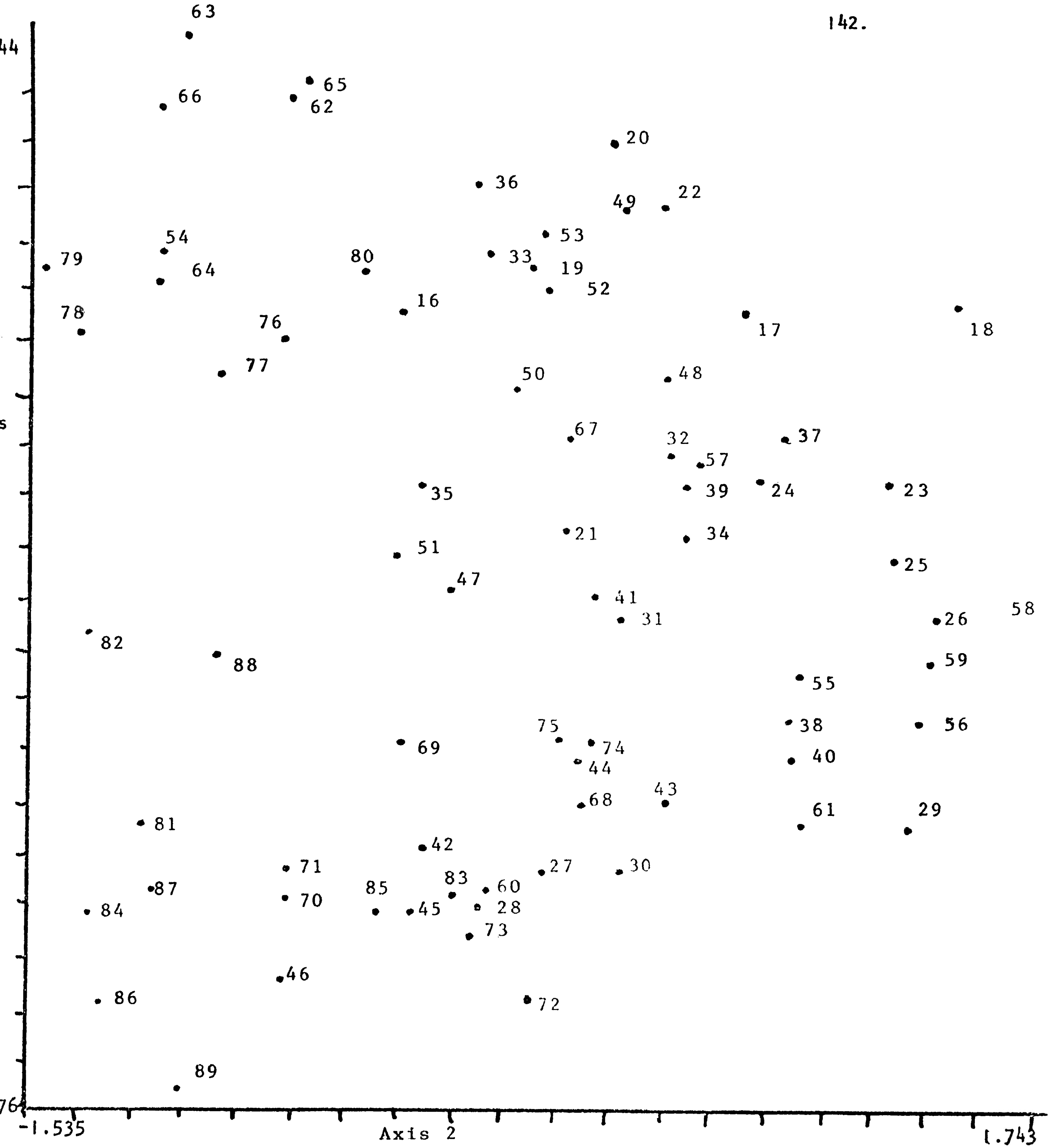


Figure R-52 Principal Components analysis (Pearce 1969) of quadrats 16 to 89
Quadrats ordinated between axes 1 and 2

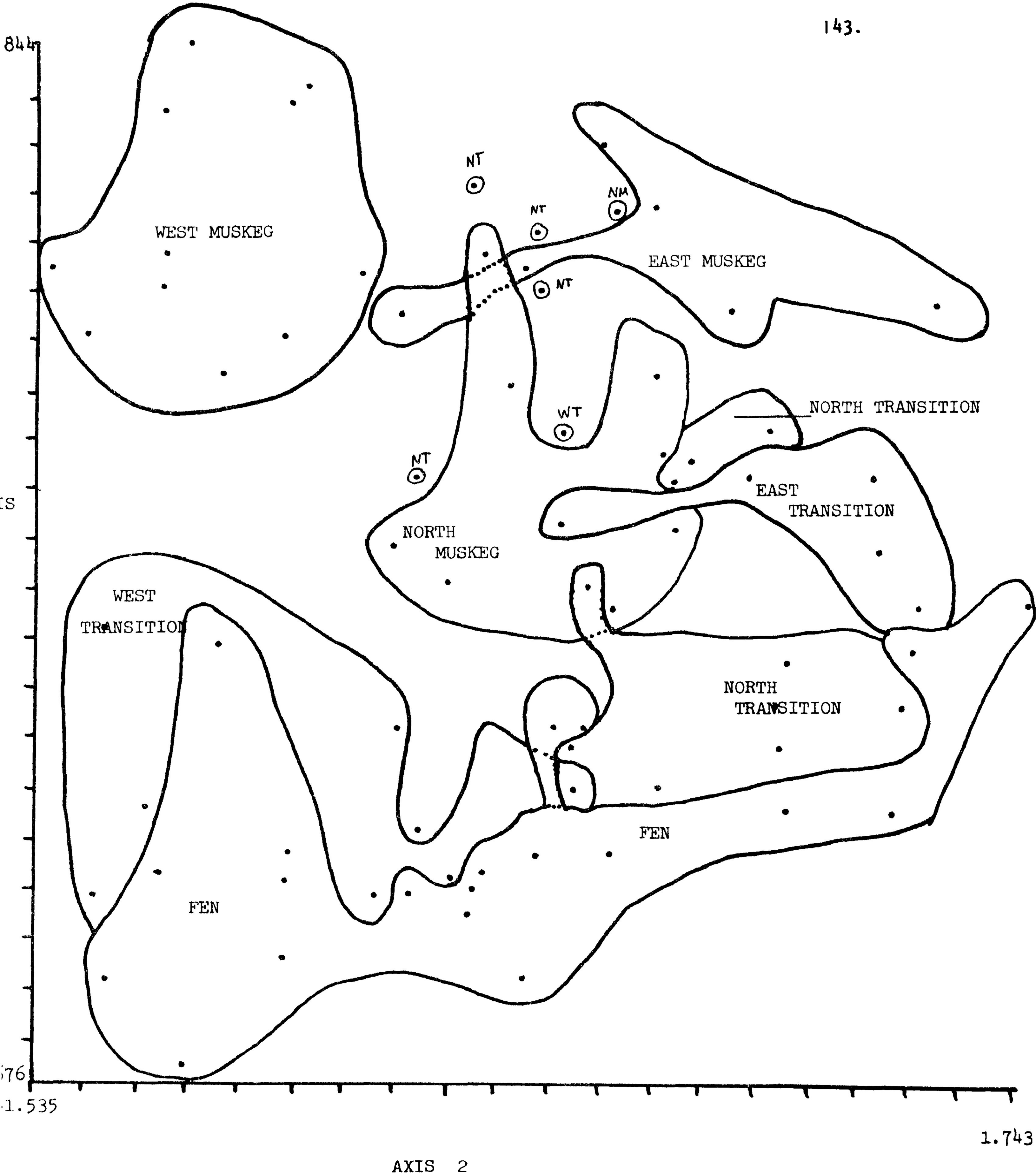


Figure R-53 Principal Components analysis (Pearce 1969) of quadrats 16 to 99 grouped by subjective classification. Circled quadrats ordinated remote from others in their group . For code see Figure R-29.

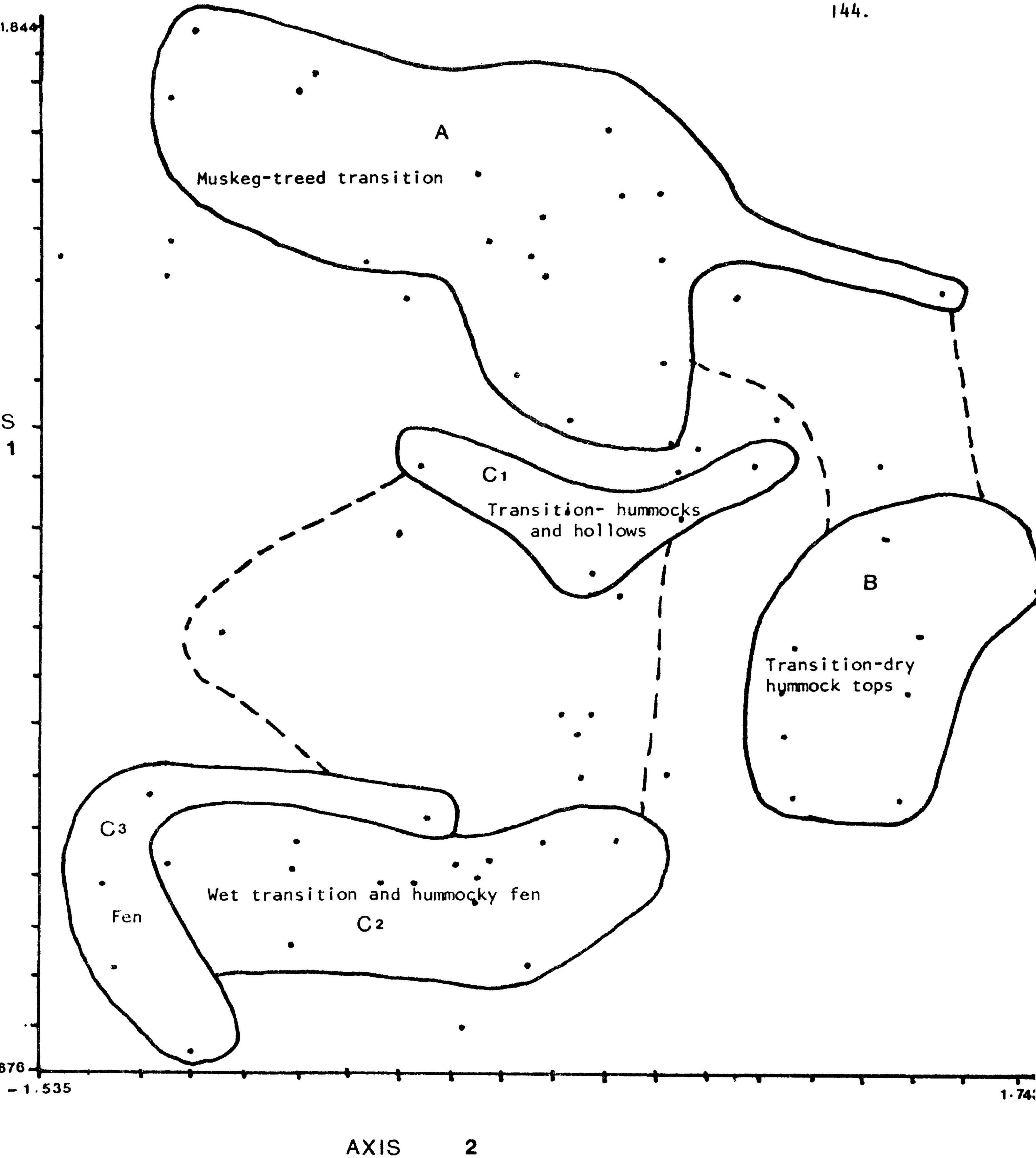


Figure R-54 Principal Components analysis of quadrats 16to 89 grouped by Normal association analysis classification. Identified by Normal group designation and ecological type. Compare to Figure R-51. Dotted lines enclose quadrats belonging to either Normal group connected by dotted lines.

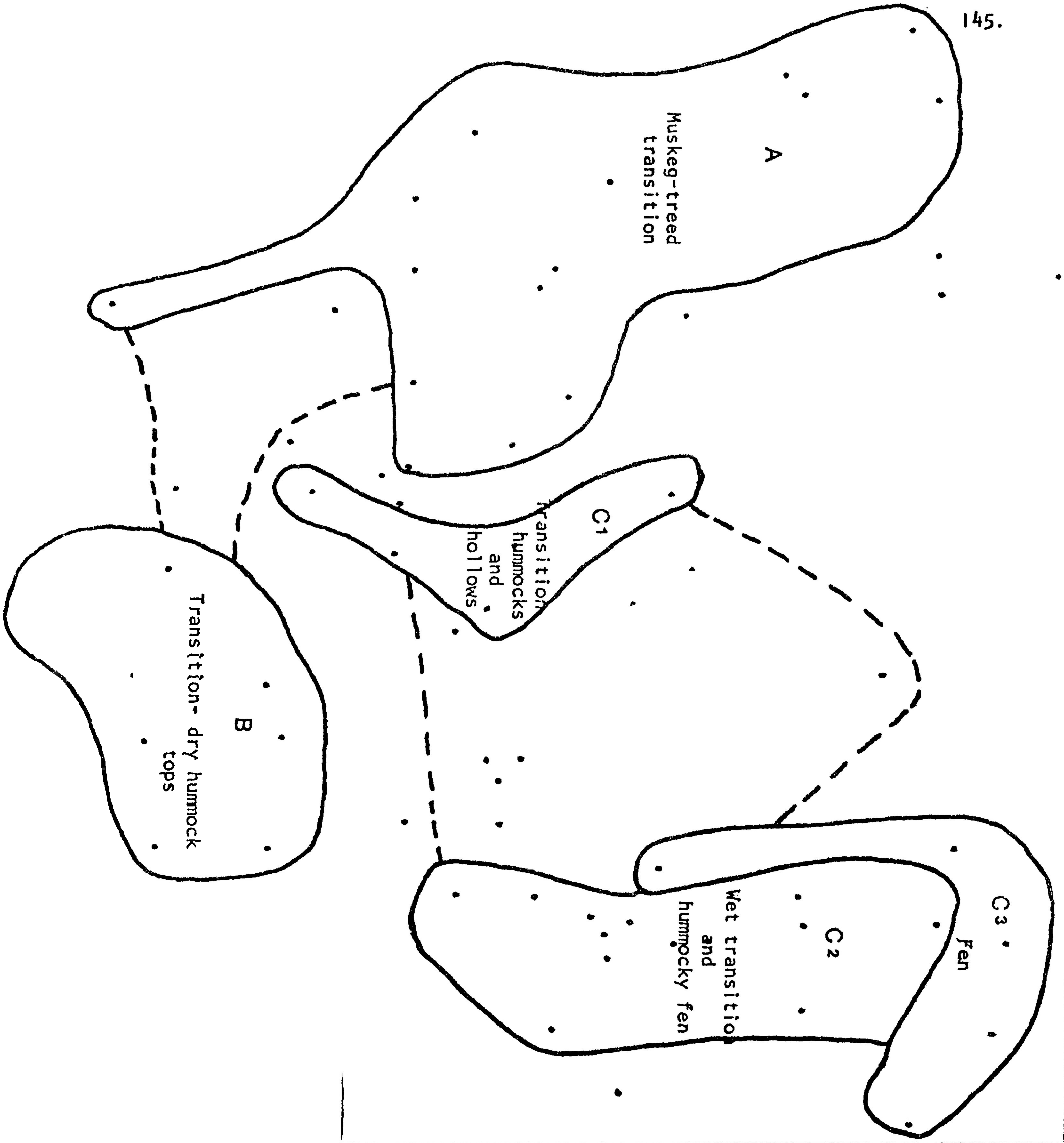


Figure R-55 P.C.A. ordination of quadrats 16 to 89 . Figure is inverted and rotated 90 degrees to illustrate similarity between Normal groups arrangement in Bray and Curtis and P.C.A. ordinations of vegetation data. Dotted lines enclose quadrats belonging to either Normal group connected by dotted lines.

Table R-56 Correlation (r) between 38 species arranged according to frequency and P.C.A. component Axes 1, 2 and 3. Transects B-F. Including proportion of total variance accounted for by floristic factors in each axis.

SPECIES \ AXIS	1	2	3	% of Total Variance
PROPORTION OF TOTAL VARIANCE	0.155 (r)	0.114 (r)	0.0750 (r)	
Chamaedaphne calyculata	0.017	0.289	0.015	3.131
Vaccinium oxycoccos	-0.066	0.143	0.329*	3.269
Equisetum fluviatile	-0.312*	-0.028	0.115	4.049
Andromeda glaucophylla	-0.346*	-0.016	0.283	4.498
Kalmia polifolia	0.032	0.281	0.106	4.454
Carex limosa	-0.211	-0.078	0.328*	4.616
Smilacina trifolia	0.236	0.328*	0.037	4.455
Picea mariana	0.418*	-0.029	-0.112	4.404
Ledum groenlandicum	0.387*	-0.162	0.093	4.211
Carex chordorrhiza	-0.094	0.112	0.188	3.270
Drosera rotundifolia	-0.023	0.154	0.269	3.131
Myrica gale	-0.038	-0.233	0.416*	3.526
Menyanthes trifoliata	-0.257	-0.204	-0.034	2.835
Sarracenia purpurea	-0.088	0.020	0.062	1.782
Larix laricina	0.088	0.006	0.242	2.676
Carex livida	-0.039	0.065	0.043	1.377
Carex exilis	-0.144	-0.070	-0.139	1.782
Utricularia radiata	-0.129	-0.123	-0.102	1.583
Phragmites communis	-0.116	-0.102	-0.046	1.583
Calamagrostis canadensis	0.030	-0.124	0.188	1.377
Carex gynocrates	0.018	-0.006	-0.004	0.945

* $p \leq 0.05$

Table R-56 Continued

SPECIES \ AXIS	1	2	3	% of Total Variance
	(r)	(r)	(r)	
Eriophorum sp.	-0.015	0.094	-0.002	0.945
Vaccinium vitis-idaea	0.110	0.002	-0.066	1.164
Carex sp.	-0.399	0.067	0.006	1.782
Scirpus caespitosus	0.082	0.005	0.054	0.719
Scirpus hudsonianum	-0.045	-0.093	0.109	0.945
Sphagnum magellanicum	-0.216	0.288	-0.060	4.535
Sphagnum fuscum	0.027	0.296*	0.226	4.616
Sphagnum recurvum	0.167	0.171	-0.177	4.498
Polytrichum juniperinum var affine	0.003	0.412*	0.009	3.756
Aulacomnium palustre	0.086	-0.073	0.239	2.835
Pleurozium schreberi	0.249	-0.206	0.148	2.676
Tomenthypnum nitens	0.250	-0.176	0.108	2.339
Dicranum polysetum	-0.015	-0.046	0.069	1.378
Sphagnum squarrosum	0.108	-0.119	0.111	1.378
Sphagnum capillifolium	0.061	0.043	-0.089	1.378
Campylium stellatum	-0.015	-0.056	0.148	1.164
Tomenthypnum nitens var falcifolium	0.072	-0.032	0.001	0.945

* ($p \leq 0.05$)

Ordinations of presence-absence floristic data resulting from Bray and Curtis ordination and Principal Components Analysis were successful at arranging quadrats in a two-dimensional plane. Quadrats were located in natural positions and were satisfactorily grouped within the ordination by either subjective or objective classification schemes.

Quadrat groups were related to one another along what appeared to be environmental gradients. These relationships will be examined in greater detail in the Vegetation-Environment relationships portion of the results section.

II. Environmental factors

Introduction

In order to describe the physical and chemical environment of the study area, several factors of climate, water level, soils, and groundwater were observed and measured regularly or sampled along transects (see Methods II).

This section deals with the results of those environmental measurements. The first factors considered were climatic, including air temperature, soil and groundwater temperatures, precipitation, relative humidity, and wind. Water and soil level fluctuations, in relation to rainfall were outlined next, then soils and groundwater characteristics (pH, loss on ignition, von Post humification, total % C, % H, % N, depth to water table, calcium concentration, conductance, ammonium and nitrate) including any relationships between measured factors. Finally, stratigraphy of the peat in a transect across the study area was described.

a) Temperature

(i) Air temperature in the study area and at Thunder Bay Airport

The first climatic factor to be examined in William Bog and at Thunder Bay Airport was air temperature. Temperature records from the two locations are outlined in Table R-57. Mean maxima and minima for each week were calculated from daily records.

Comparison between these two sites was necessary to the description of the local climate in William Bog.

Records from Table R-57 and Graph R-58 indicate that mean temperatures were similar in the study area and at the Thunder Bay Airport. The study area exhibited higher temperature maxima over the period of study, the only exception being the mean value for the week of November 19. This value was composed of three measurements only (November 23,24,25). Minimum temperatures were lower in the study area during the period between June 29 and September 14. Later in the season minimum temperatures were similar. After the week of October 5 minima in the study area were higher than those of the Airport, likely because freezing temperatures produced problems with the accuracy of temperature readings from the hygrothermograph resulting in an incomplete temperature record. Overall, the study area appeared to suffer greater temperature extremes than did the Thunder Bay Airport 3 km south west.

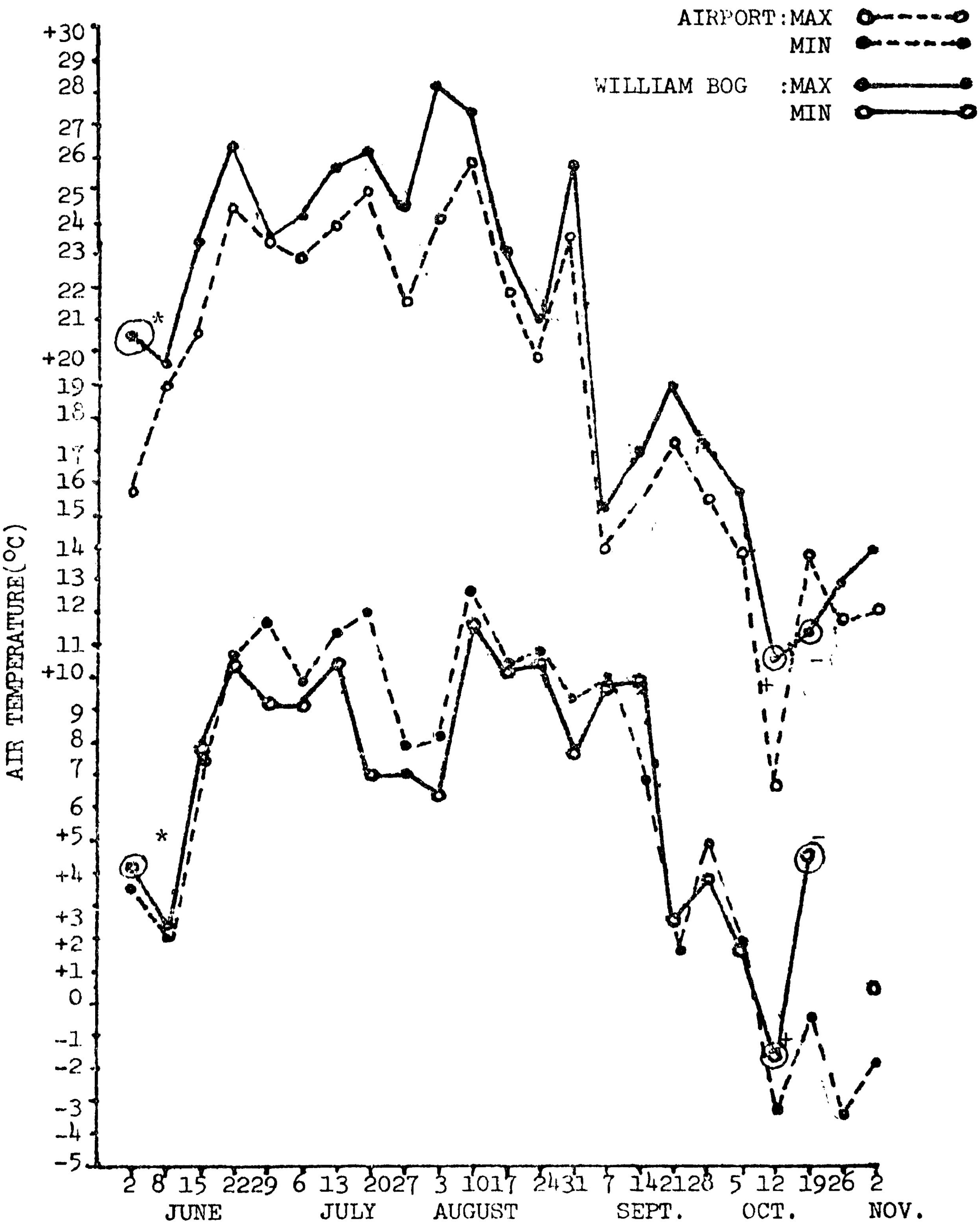
The time between last and first frost in the study area was 42 days, while at the Airport it was 100 days (see Table R-59). The lowest 1979 minimum temperature recorded in the study area was $-41^{o}C$ (January Fen minimum at 1.0 m ev.) and $-39^{0}C$ (January 1979 minimum) at the Airport. The study area appeared to have a considerably shorter frost free period.

This data indicated that there was a difference between these two sites when their temperatures were compared. William Bog seems to have the more extreme climate.

Table R-57 $\overline{X}$ Weekly air temperature maxima and minima at Thunder Bay Airport and William Bog located 3 km apart.

1978 DATE	William Bog Max	Min	$\overline{X}$	Thunder Bay Airport Max	Min	Mean	Diff of $\overline{X}$'s
May 25							
June 2	20.5	4.2	12.4	15.7	3.8	9.8	2.6
8	19.6	2.4	11.0	18.8	2.0	10.4	0.6
15	23.4	7.7	15.6	20.3	7.5	13.9	1.7
22	26.3	10.4	16.9	24.1	10.3	17.2	-0.3
29	23.5	9.2	17.1	23.2	11.4	17.3	-0.2
July 6	24.1	9.2	16.7	22.6	9.7	16.2	0.5
13	25.6	10.4	18.0	23.7	11.2	17.5	0.5
20	26.2	7.0	16.6	24.7	11.8	18.3	-1.7
27	24.6	7.0	15.8	21.3	7.6	14.5	1.3
Aug. 3	28.2	6.3	17.3	23.6	7.8	15.7	1.6
10	27.3	11.6	19.5	25.6	12.5	19.1	0.4
17	23.1	10.1	16.6	21.7	10.2	16.0	0.6
24	21.0	10.4	15.7	19.5	10.4	15.0	0.7
31	25.6	7.6	16.6	23.6	9.3	16.5	0.1
Sept. 7	15.1	9.6	12.4	13.8	9.8	11.8	0.6
14	16.9	9.8	13.4	15.2	6.4	10.8	2.6
21	18.9	2.6	10.8	17.1	1.6	9.4	1.4
28	17.1	3.7	10.4	15.2	4.8	10.0	0.4
Oct. 5	15.6	1.6	8.6	13.8	1.6	7.7	0.9
12	10.5	-1.6	4.5	6.3	-3.4	1.5	3.0
19	11.3	4.6	8.0	13.5	-0.8	6.3	1.7
26	12.8	- *		11.4	-3.6	3.9	--
Nov 2	13.9	0.5	7.2	11.9	-2.0	5.0	2.2

* min < -5



GRAPH R-58. Mean weekly Air temperature at Thunder Bay Airport 3 Km. from William Bog June 2 to November 2, 1978. Mean weekly air temperature at William Bog Measured by thermograph in east transition zone.

* Mean of June 5, 6, 7, 8, only
\+ Mean of October 12, 13, 14 only
\- Mean of November 23, 24, 25 only

Table R-59 Frost free period in the study area and Thunder Bay Airport (3 km south)

Study Area

June 22 to August 3, 1978

42 days

lowest minimum -41°C (Jan. minimum - Fen at 1 m.ev.)

highest maximum +33°C (July 10 and 27 - transition zone maximum)

Thunder Bay Airport

June 13 - Sept. 22, 1978

100 days

Mean yearly frost free period (Anon., 1974) 101 days

lowest minimum -39.0°C (January, 1978 min)

highest maximum +31.6°C (July 6, 1978 maximum)

(ii) Air temperature maxima and minima in muskeg, transition and fen sites

Air temperature maxima and minima at ground level and 1 metre in elevation in muskeg, transition and fen sites were recorded in Tables R-60 and R-61.

When mean temperatures were compared between ground level and 1 metre above ground in muskeg sites there were no temperature differences between elevations greater than 1.0°C measured

Continued on page 157.

Table R-60 Temperature extremes at 1 metre elevation recorded in three sites within the study area.

1978/79	°C MUSKEG			°C TRANS.			°C FEN		
MONTH	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
June	32.5	-1.1	15.7	27.0	1.6	14.3	28.3	2.5	15.4
July	31.7	3.0	17.4	30.0	7.0	18.5	31.3	4.5	17.9
August	30.9	1.6	16.3	27.1	3.7	15.4	27.7	2.2	15.0
September	25.8	-0.5	12.7	22.0	4.3	13.1	23.5	0.8	12.1
October	21.5	-7.7	6.9	18.3	-5.2	6.6	19.1	-6.9	6.1
November	18.0	-31	-6.5	20.0	-28	-4.0	19.5	-30	-5.3
December	0	-32	-16.0	2.5	-33	-15.3	2.0	-33	-15.5
January	-4	-38	-21.0	-1.0	-40	-20.5	-2.0	-41	-21.5
February	-2	-40	-21.0	-1.0	-39	-20.0	-1.0	-40	-20.5
March	5.0	-26	-10.5	8.0	-23	-7.5	7.0	-25	-9.0
April	16.0	-10	3.0	17.0	-8	4.5	16.0	-8	4.0
May	+27	-5	11.0	21.5	-4	8.8	21.5	0	10.8

Table R-61 Temperature extremes at ground level at three sites within the study area.

	MONTH	°C MUSKEG MAX	MIN	MEAN	°C TRANS. MAX	MIN	MEAN	°C FEN MAX	MIN	MEAN	
1978	June	32.3	-1.5	15.4	30.6	-1.1	14.8	27.9	1.6	14.8	
	July	33.2	1.3	17.3	30.8	3.7	17.2	31.3	6.2	18.7	
	August	32.1	-0.2	16.0	28.9	1.1	15.0	27.8	3.7	15.8	
	September	25.0	-1.5	11.8	26.1	0	13.1	25.0	1.4	13.2	
	October	18.0	-2.4	7.8	21.6	-7.9	6.9	21.8	-5.8	8.0	
	November	14.3	-16.5	-1.1	17.5	-15.3	1.1	12.0	-11.0	-5.5	
	December	-	-	-	-		-	-	-	-	BURIED UNDER SNOW
1979	January	-		-	-		-	-	-	-	BURIED
	February	-	-	-	-		-	-	-	-	BURIED
	March	-		-	-	-	-	-	-	-	BURIED
	April	+18	-22	-2.0	16	-11.5	2.3	17	-12	2.5	MINIMA OVER DEC.-APRIL UNDER SNOW
	May	+27	-4	11.5	25.5	-3	11.3	23	0	11.5	

from June through October. From June through September the higher temperatures were always recorded at 1 metre above the surface. In October ground level was slightly warmer. In November it was 5.4°C warmer at ground level.

Maximum temperatures in the muskeg were slightly higher at ground level in July and August and lower in October and November. Minimum temperatures at ground level were lower than those of 1 metre in June, July, August and September. Minima at ground level were much warmer than those of 1 metre in October and November.

In the muskeg temperatures were more extreme at ground level during June, July, August and September. This trend was reversed in October and November where ambient air temperatures were more extreme than those at ground level.

Mean temperatures in the transition zone, at ground level and at 1 metre, were very similar. In July it was 1.3°C cooler at ground level and in November it was 5.1°C warmer. Minima were consistently lower from June through October at ground level, mean difference was 3.1°C. In November it was 12.7°C colder 1 metre above ground level. Maxima were consistently higher at ground level, from June to October, mean difference was 2.7°C. In November it was 2.5°C cooler at ground level.

In the transition zone the greatest temperature extremes were experienced at ground level from June through October. In November the greatest temperature extremes were recorded by the thermometer suspended 1 metre above the ground.

In the fen it was cooler at ground level in June. From July through October mean difference in temperature was 1.2°C warmer at ground level. In November the mean temperatures were 0.2°C cooler at ground level. Minima were consistently warmer at ground level from July through October, mean difference is 1.0°C. In November the minimum temperature was 1.9°C warmer at ground level and in June it was 1°C cooler. Temperature maxima were cooler at ground level in June and November. They were very similar in July and August, and warmer at ground level in September and October.

Temperatures at ground level and 1 metre were more similar in the fen than in the muskeg or transition. The transition zone exhibited the greatest extremes in temperature at ground level and had the highest mean difference between ground level and 1 metre. Mean temperatures for June through March at 1 metre differed very little between sites, muskeg was -0.6°C, fen -0.5°C and transition +0.6°C. Mean temperatures at ground level from June through November were also very similar, fen 10.8°C, muskeg 11.2°C, transition 11.4°C. At both levels it was slightly warmer in the transition zone. At ground level it was coolest in the fen and at 1 metre it was slightly cooler in the muskeg.

(iii) Soil and groundwater temperatures

A) Extremes over a twelve month period

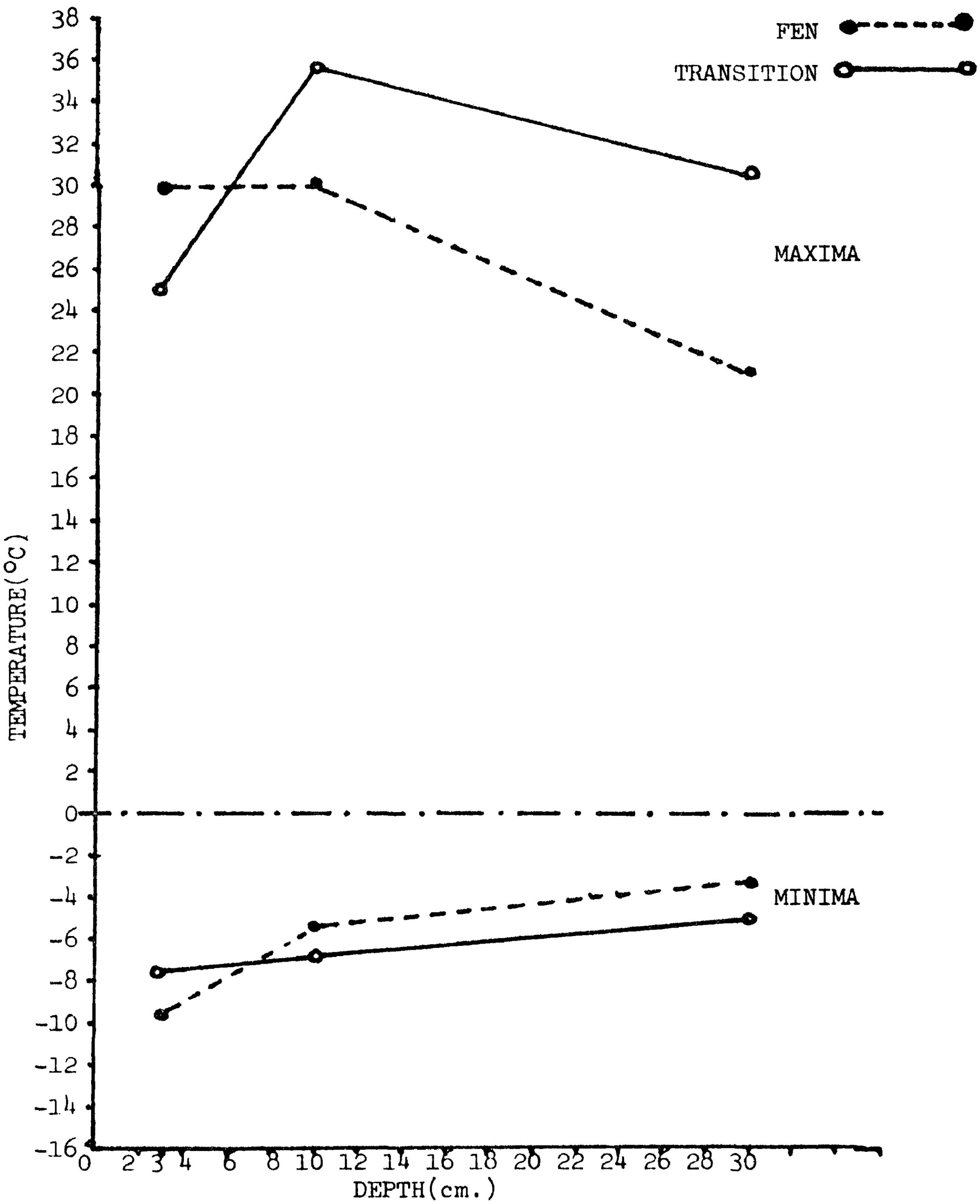
Temperature extremes over a twelve month period were measured at three depths in three locations within the study area and are recorded in Table R-62.

The transition zone had higher temperature maxima than did the fen. The low reading at -3 cm in depth might have been due to slippage of the maximum temperature indicator. The lowest minimum temperature was in the fen at -3 cm in depth (-9.4°C). Temperature maxima tended to decrease with depth in both the fen and transition zone, maxima were higher in the transition zone (see graph R-63). Temperature minima tended to increase with depth and were slightly higher in the fen. The transition zone exhibited the greatest extremes in temperature -10 cm in depth (35.6°C and -6.7°C) while the fen exhibited the greatest extremes at 3 cm below the surface (28.9°C and -9.4°C).

Table R-62 Temperature extremes over a 12 month period in two locations in the study area.

Depth below surface

LOCATION	-3 cm		-10 cm		-30 cm		
	MAX	MIN	MAX	MIN	MAX	MIN	
Fen	28.9	-9.4	30.0	-5.6	21.1	-3.3	°C
East Trans.	25	-7.8	35.6	-6.7	30.6	-5.0	°C
East Bog	-	-		-	-		lost



GRAPH R-63. Temperature extremes over a twelve month period at 3cm, 10cm, and 30cm below the peat surface in eastern transition and fen sites (1977-1978).

B) Temperature stratification in *Sphagnum* hummocks

Temperatures measured within *Sphagnum* hummocks were plotted on graphs R-64 through R-68.

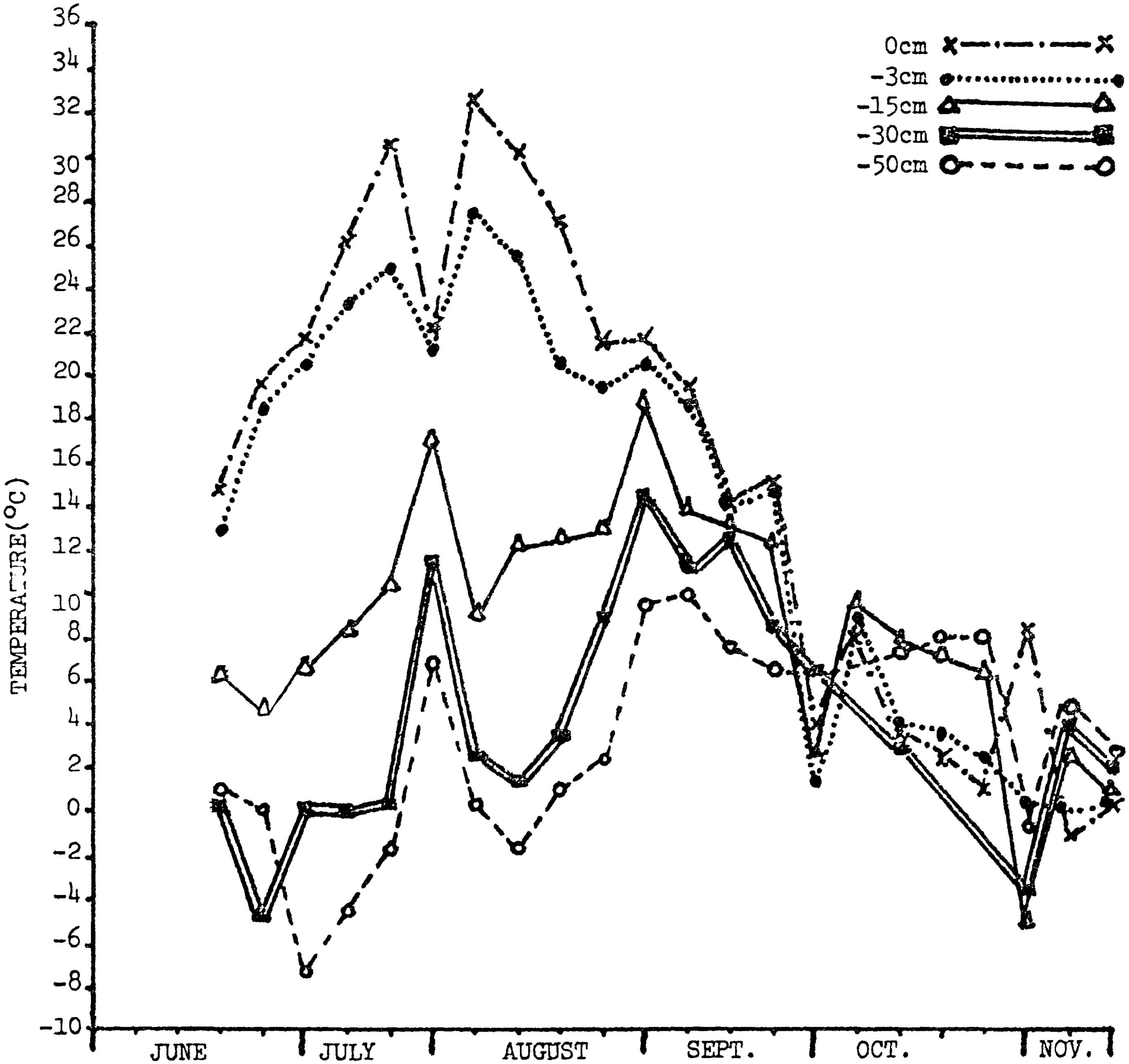
Graph R-64 illustrates temperature stratifications within a hummock present in muskeg vegetation to the east of the fen. The greatest variation in temperature with depth was in the months of June, July and August. The surface temperature reached a maximum of 32.6°C on August 1, 1978, while the centre of the hummock at depths of 30 cm and 50 cm remained frozen until July 17, 1978. Temperatures within the hummock approached uniformity during September, October and November.

Graph R-65 presents temperature variations in a muskeg hummock on the western side of the fen. The core of this hummock was not frozen until November 7, 1978. Temperatures were less varied (at depths of 15 cm, 30 cm and 50 cm) than those of bog hummocks to the east of the fen (see graph R-65).

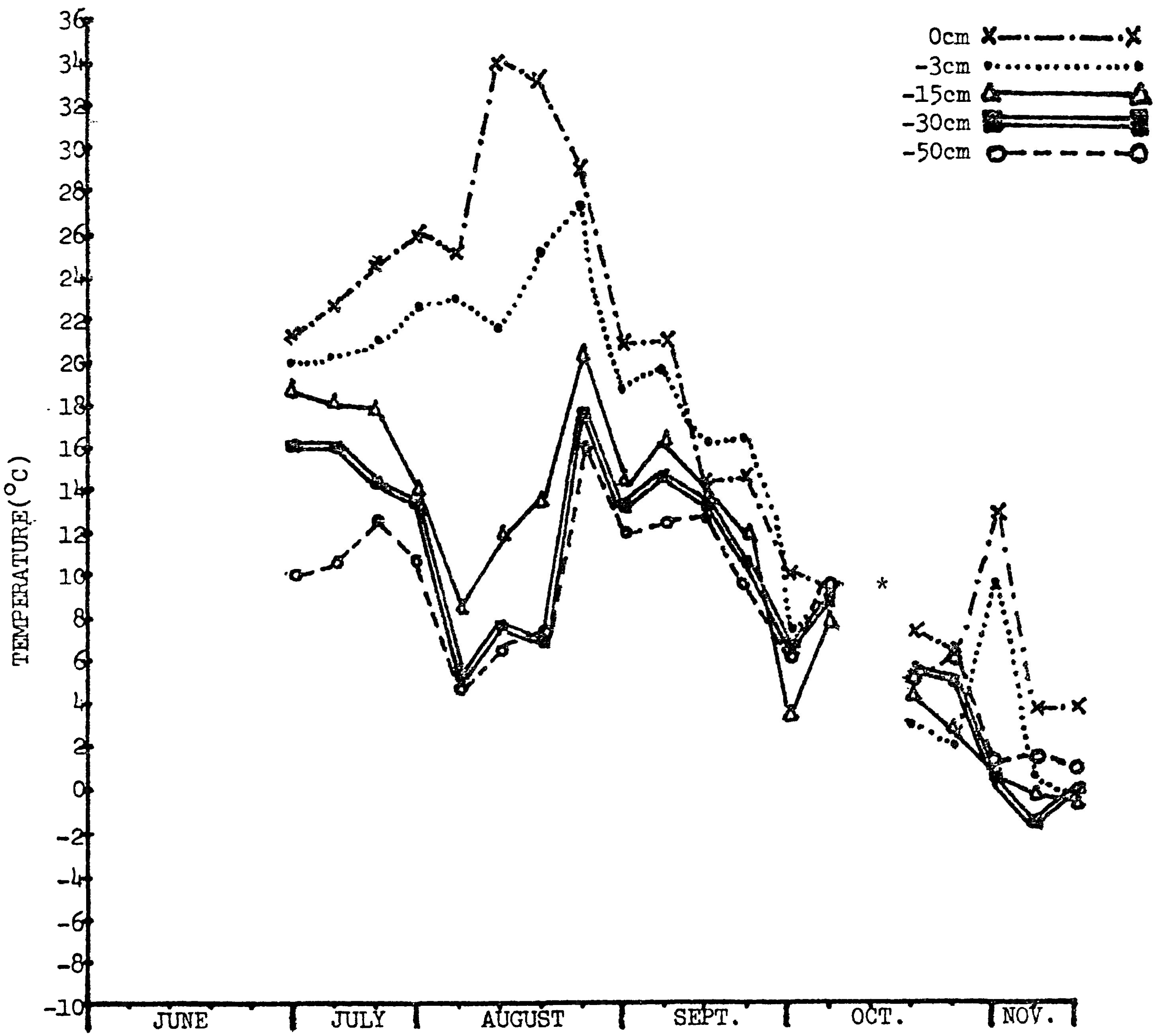
Maximum surface temperature was 34.0°C on August 7, 1978. Temperature variation over depth decreased in September, October and November.

Graphs R-66 and R-67 illustrate temperature stratifications in *Sphagnum* hummocks in transition zones to the east (graph R-66) and west (graph R-67) of the fen. The eastern hummock exhibited two zones of temperatures. The surface and -3 cm regions were considerably warmer than those at depths 15 cm, 30 cm and 50 cm below the surface.

Continued on page 167.

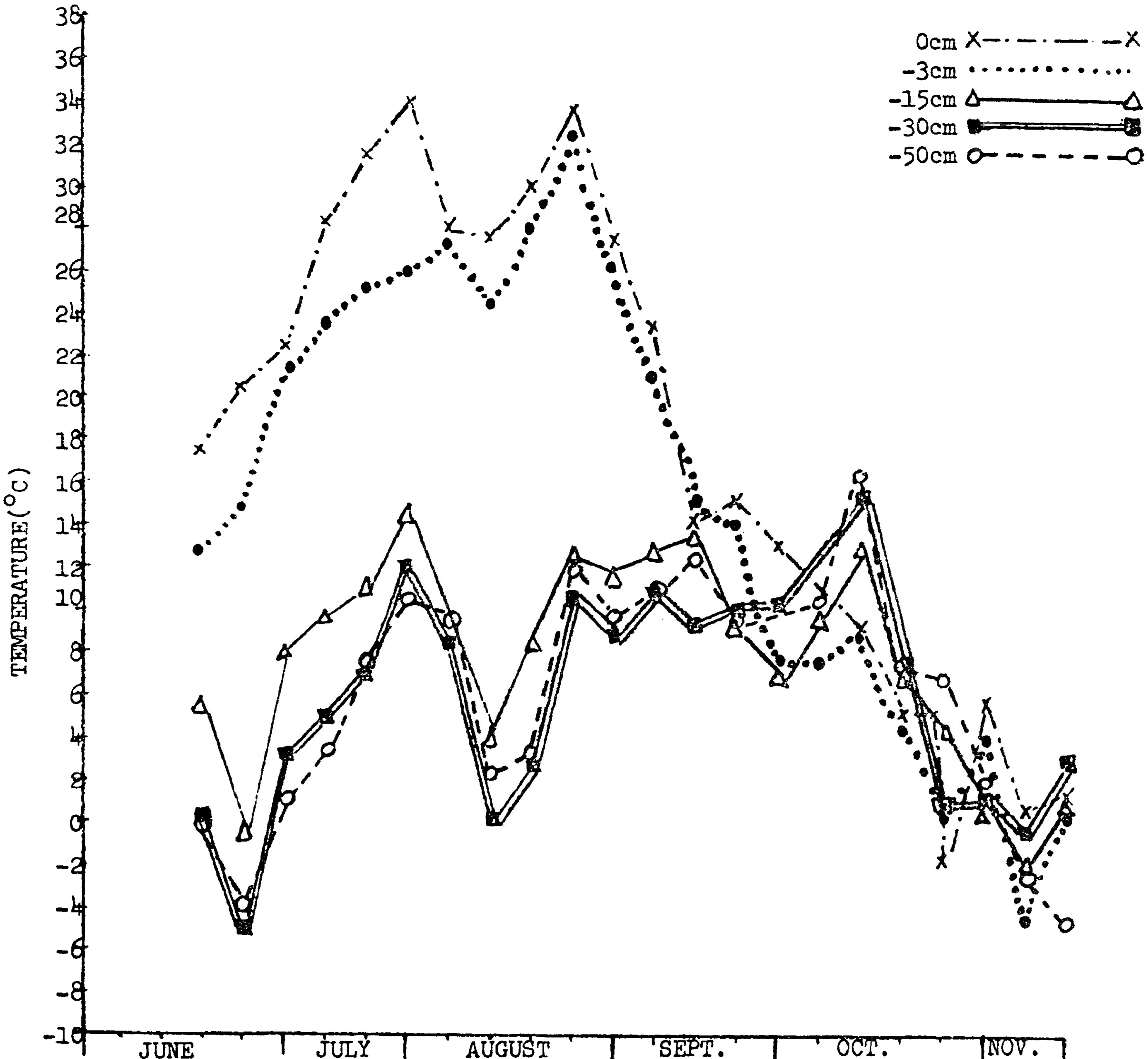


GRAPH R-64. Temperature stratification over five depths in a *Sphagnum* spp. hummock in an eastern muskeg site(June 7-Nov. 14,1978).

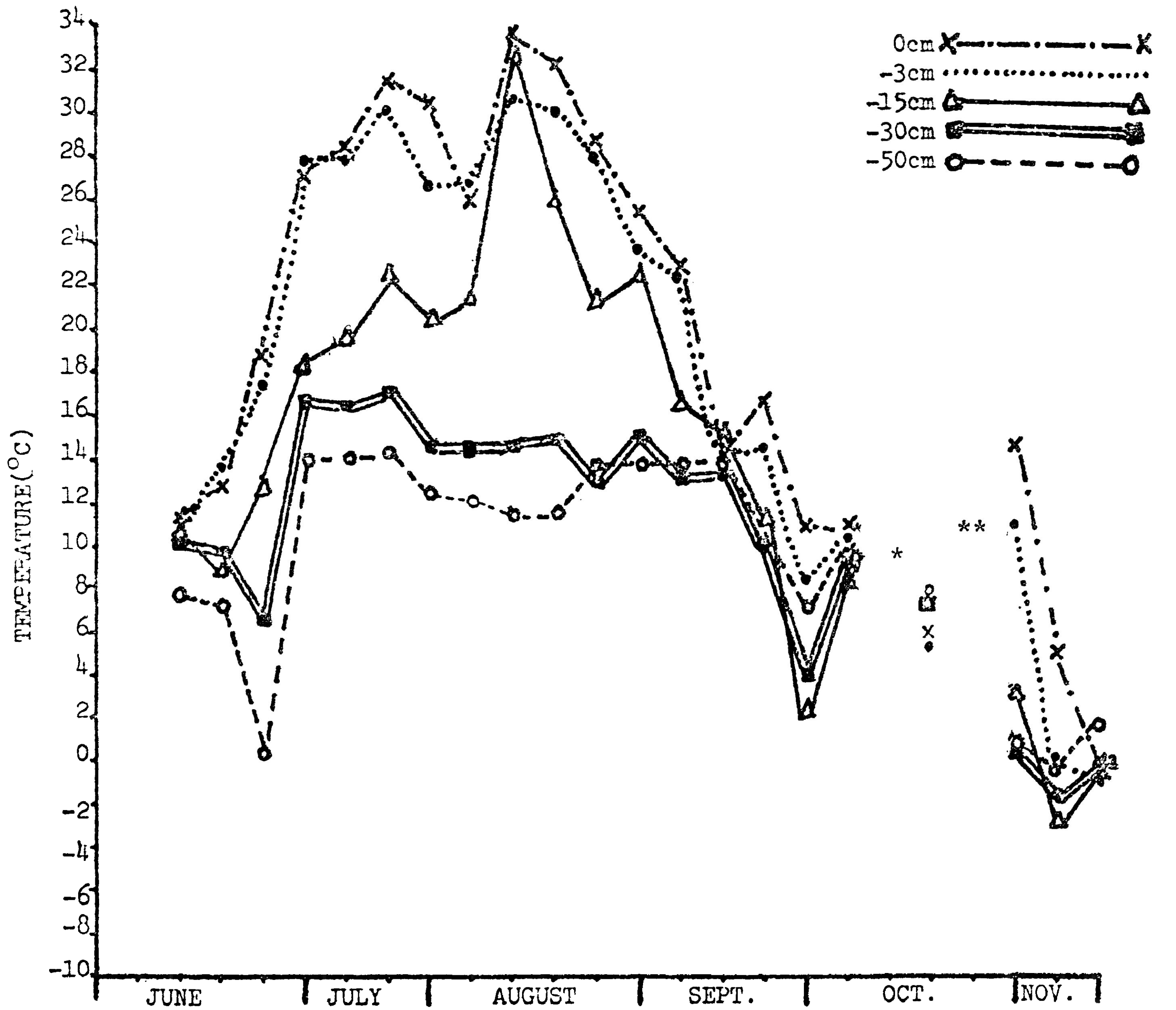


GRAPH R-65. Temperature stratification over five depths in a *Sphagnum* spp. hummock in a western muskeg site (June 30- Nov. 14, 1978).

* No readings taken on October 9



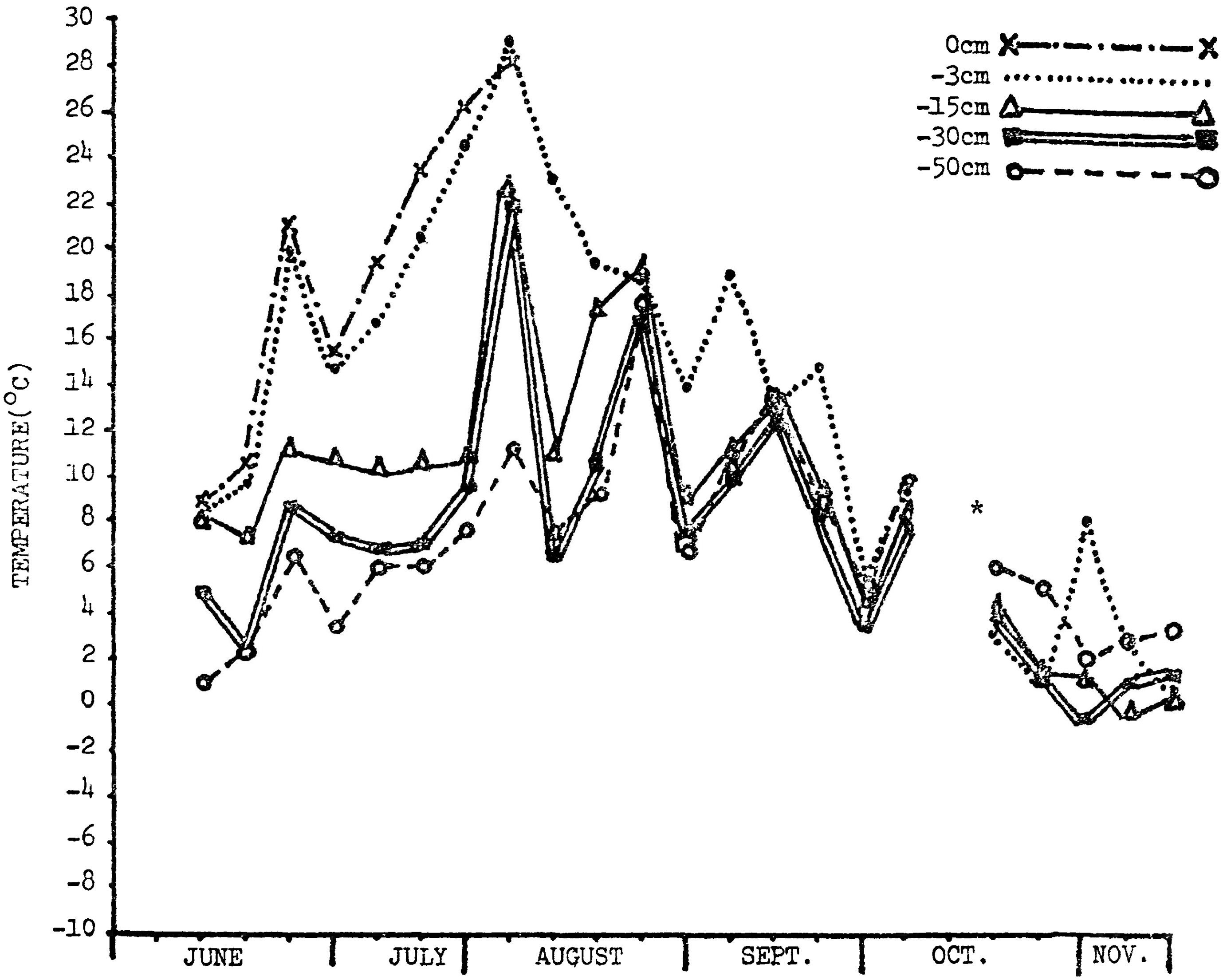
GRAPH R-66. Temperature stratification over five depths in a <u>Sphagnum</u> spp. hummock in an eastern transition zone site (June 15- Nov. 14, 1978).



GRAPH R-67. Temperature stratification over five depths in a *Sphagnum* spp. hummock in a western transition zone site(June 15- Nov. 14,1978).

* no reading taken October 9

** West transition system inoperative October 23



GRAPH R-68. Temperature stratification over five depths in a _Sphagnum_ spp. hummock in a fen site (June 15- Nov. 14, 1978).

* No readings taken October 9

Temperature variation with depth was reduced in September, October and November. The western transition zone hummock did not exhibit temperature stratifications similar to the east side hummock. Western transition hummock temperature was uniformly reduced with depth. Variation was greatly reduced during September, October and November.

Graph R-68 illustrates temperature stratification in a *Sphagnum* hummock in the fen. Fen hummocks showed the least variation in temperature with depth of all hummocks examined.

The general trend in all *Sphagnum* hummocks examined was that of great variation in temperature with depth early in the growing season. Hummocks could remain frozen at depths of 50 cm beneath the surface late into July. Later in the season (August, September, October) temperatures within hummocks tended toward uniformity, regardless of depth.

Hummocks in muskeg sites showed the greatest extremes early in the season. Transition zone hummocks were warmer near the surface and fen hummocks showed the least variation in temperature with depth.

C) Air and soil temperature profiles in *Sphagnum spp.* hummocks

Temperature profiles were constructed from data collected with copper-constantan thermocouples located above and within *Sphagnum spp.* hummocks in west side fen, eastern transition zone and muskeg east of the fen (see Methods II). Graphs R-71 through R-82 illustrate temperature stratification in and above hummocks on June 23, August 7,

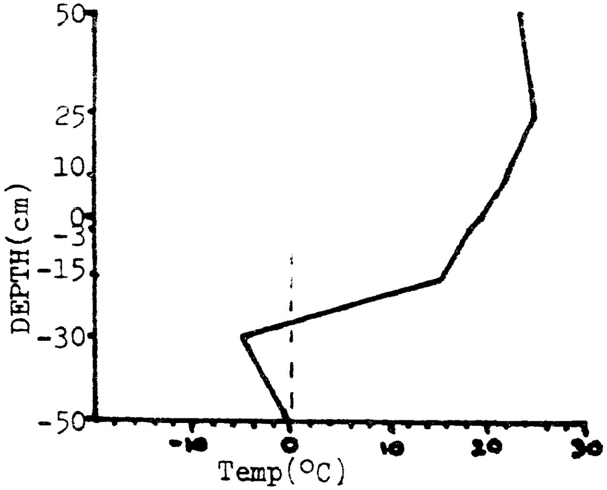
continued on page 170

September 18 and November 14 in each of the three sites.

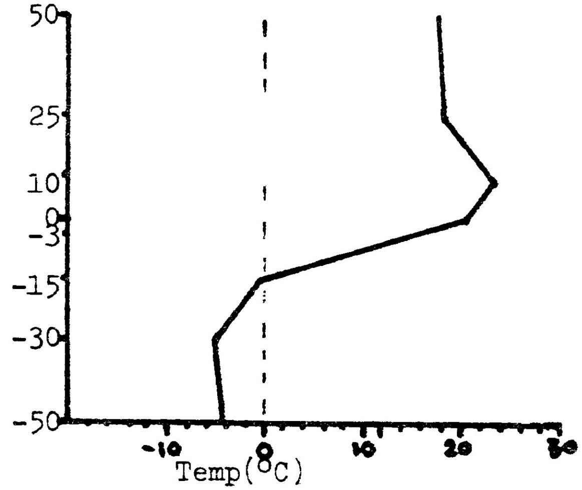
There was a large difference between air and peat temperatures on June 23, 1978. The greatest variation between air temperature and soil temperature occurred in the transition zone. Warmest temperatures occurred 10cm above the surface in the fen (25.1°C) and transition zone (23.8°C) while in the muskeg, the warmest temperature (24.5°C) occurred at 25 cm above the surface. On June 23 muskeg and transition hummocks cores were frozen. The transition hummock's core was frozen at 15 cm below the surface. The muskeg hummock core was frozen from 30 cm below the surface. No portion of the fen hummock was frozen on June 23.

Profiles of air and hummock temperature on August 7, 1978 were similar to those of June 23. Warmest temperatures occurred 10 cm above the surface in the fen (32.2°C) and transition (37.8°C) and at 25 cm and 50 cm above the surface in the muskeg (35.5°C). Hummock cores warmed up, but were still frozen at -50 cm (-1.5°C) in the muskeg and at -30 cm (0°C) in the transition. The transition hummock was not frozen at -50 cm (2.3°C). The ice at 30 cm below the surface probably an ice lense within the hummock's centre. The least variation between air and soil temperature was in the fen.

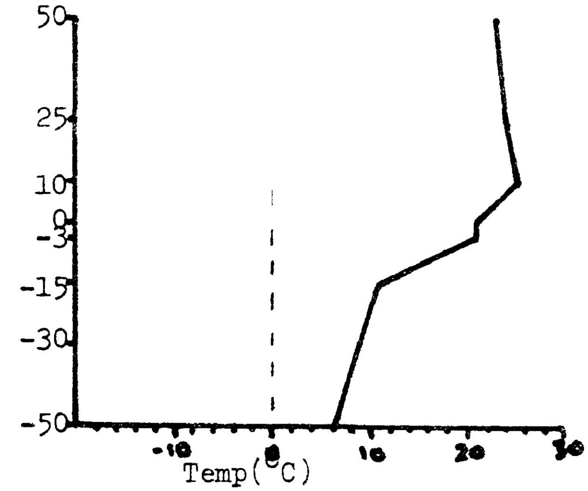
Air and soil temperatures were almost uniform on September 18, 1978. The greatest variation in temperature was in the transition zone hummock, while the least variation was in the fen. Hummock cores were completely thawed in all sites.



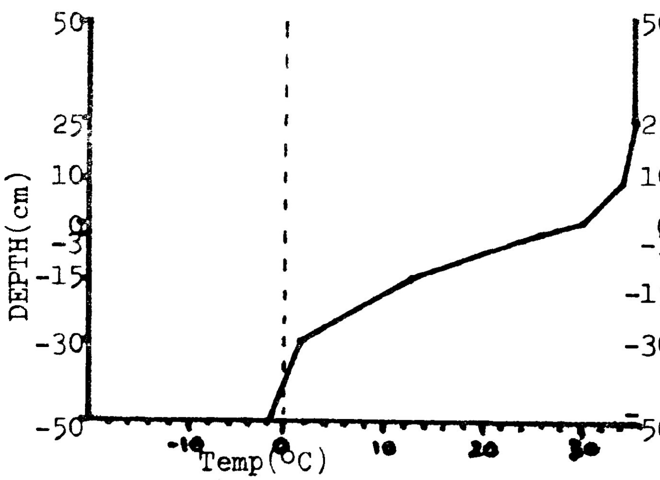
GRAPH R-71.Muskeg-June 23,1978.



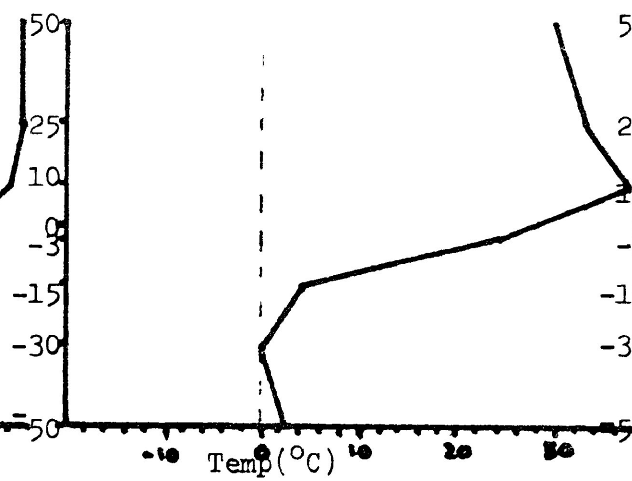
GRAPH R-72.Transition-June 23, 1978.



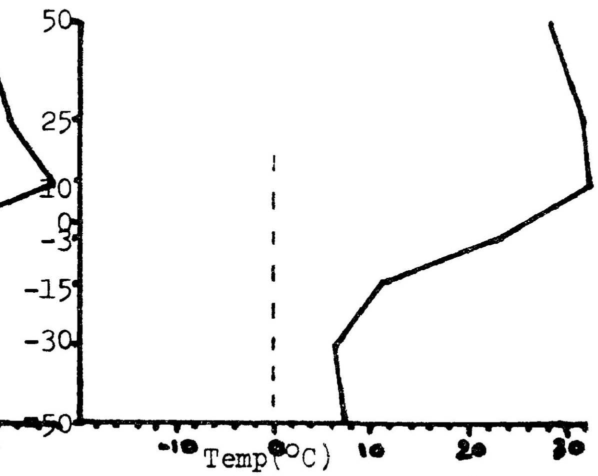
GRAPH R-73.Fen-June 23,1978.



GRAPH R-74.Muskeg-Aug.7,1978.

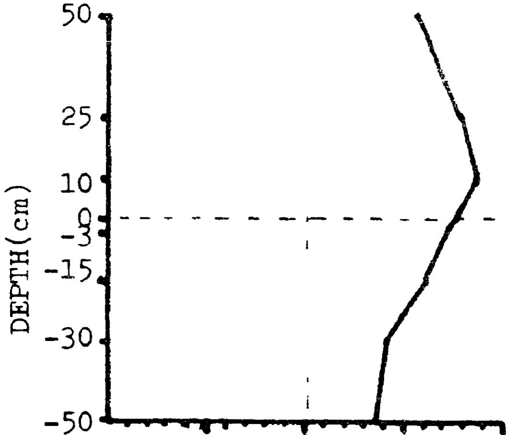


GRAPH R-75.Transition-Aug.7,1978.



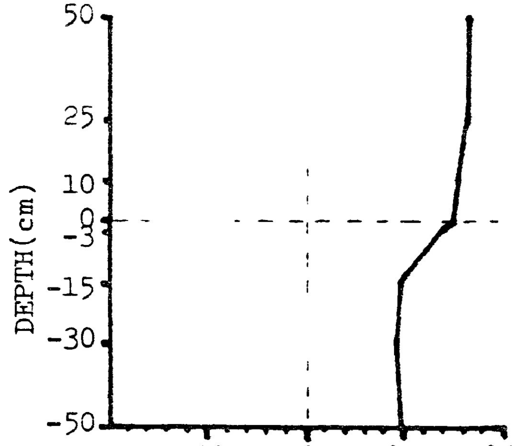
GRAPH R-76.Fen-Aug.7,1978.

GRAPHS R-71 to R-76.Air-peat temperature profiles in <u>Sphagnum</u> spp. hummocks in three sites representing muskeg,transition,and fen in June and August 1978.



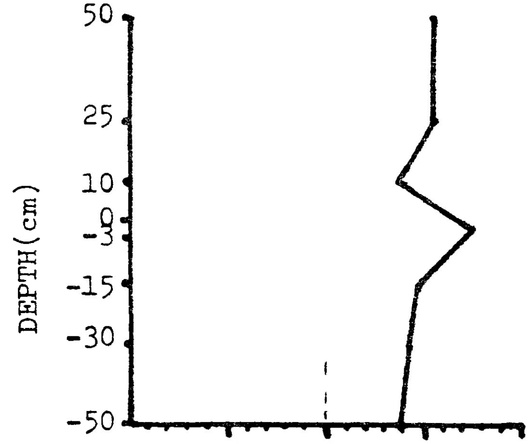
GRAPH R-77.Muskeg-Sept.18,1978.

Temp(°C)



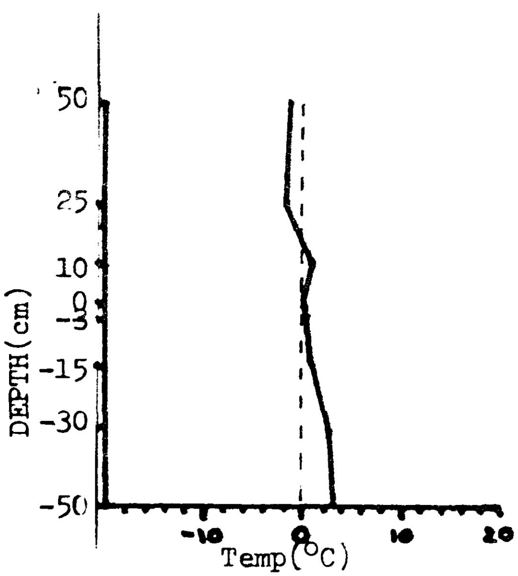
GRAPH R-78.Transition-Sept.18, 1978.

Temp(°C)

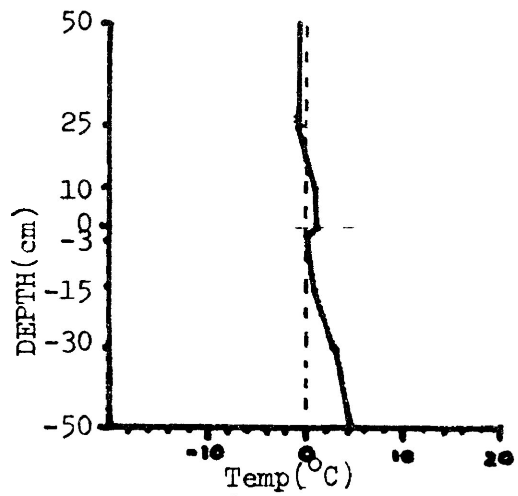


GRAPH R-79.Fen-Sept.18,1978.

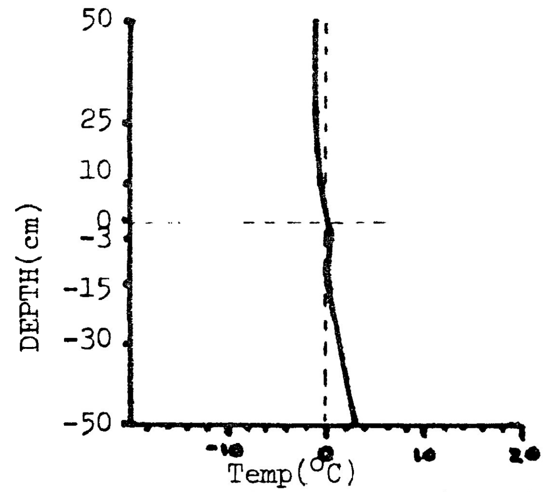
Temp(°C)



GRAPH R-80.Muskeg-Nov.14,1978.



GRAPH R-81.Transition-Nov.14, 1978.



GRAPH R-82.Fen-Nov.14,1978.

GRAPHS R-77 to R-82.Air-peat temperature profiles in <u>Sphagnum</u> spp. hummocks in three sites representing muskeg,transition,and fen in September and November 1978.

By November 14, 1978 air temperatures in all sites were below zero, while surface and underground temperatures were above zero. Warmest temperatures in all three sites occurred at 50 cm below the surface, 3.2 C in fen and muskeg hummocks and 4.5 C in the transition zone hummock.

Temperature profiles within and above *Sphagnum* hummocks were the most diverse on June 23. Core temperatures warm up over the season until November 14 when the profiles were almost uniform and show no large variation with depth. Muskeg hummocks took the longest to thaw and tend to thaw from the bottom up. Transition hummocks thaw from the bottom and top leaving an ice lense in their centre, this lense remained well into August. Fen hummocks thaw very early in the season and had fairly uniform temperatures throughout.

b) Wind

Wind direction and a subjective measurement of intensity (see Methods) were noted throughout the period of study and were recorded in graphs R-83 and R-85 and Figure R-84.

Westerly winds were most common, especially during the months of June, July and August. Strong east winds were common in March, April. Northwest winds were prevalent in December and January.

Winds tended to blow up and down the fen, rather than across it.

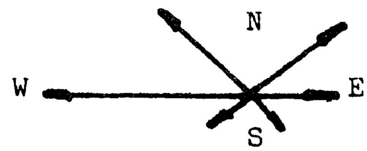
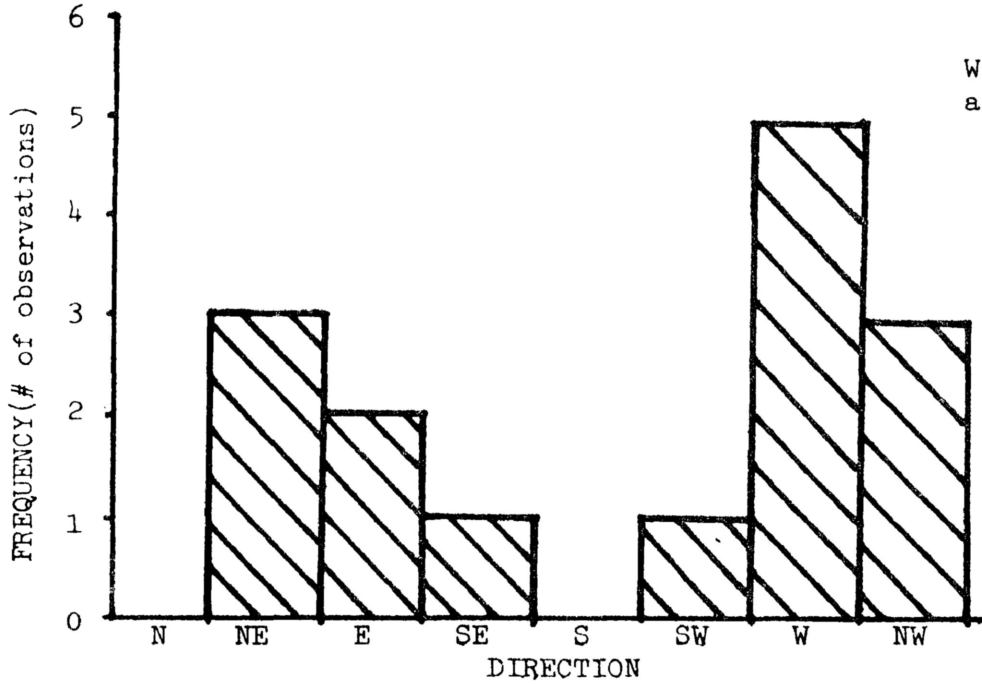
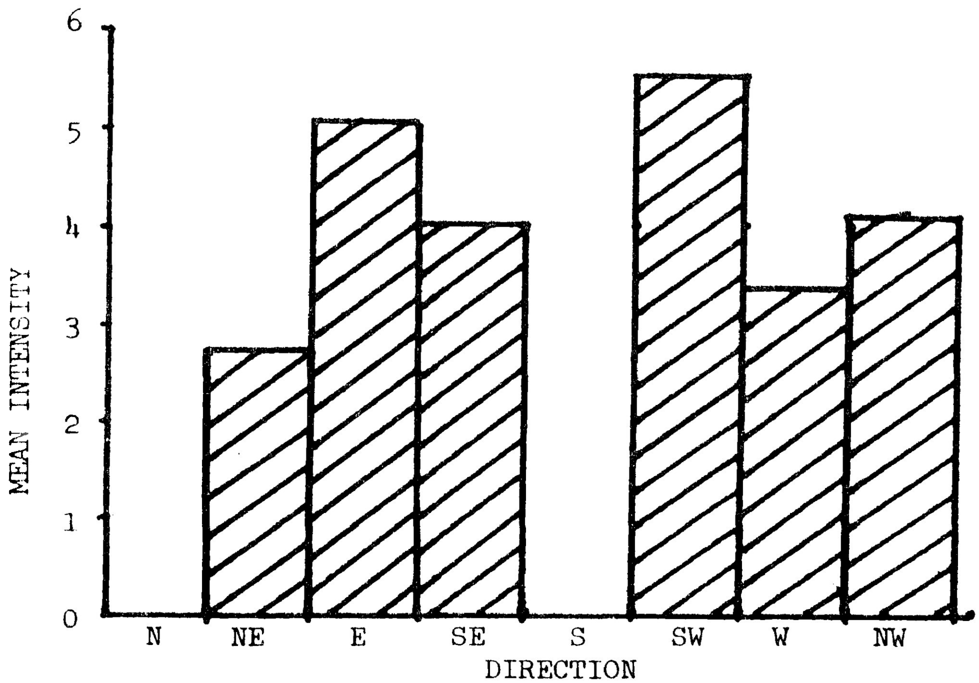


FIGURE R-84.
Wind rose for the study area and Thunder Bay Airport.

Subjective Scale:
1.light
2.breeze
3.moderate
4.brisk
5.strong



GRAPH R-83.Wind direction and frequency in the study area determined by weekly observation.



GRAPH R-85.Wind direction and empirically determined intensity in the study area.

c) Precipitation and relative humidity

(i) Snowfall

Point measurements of snowfall in eight sites representative of muskeg, transition and fen were averaged and plotted in graph R-86. See figure M-4.

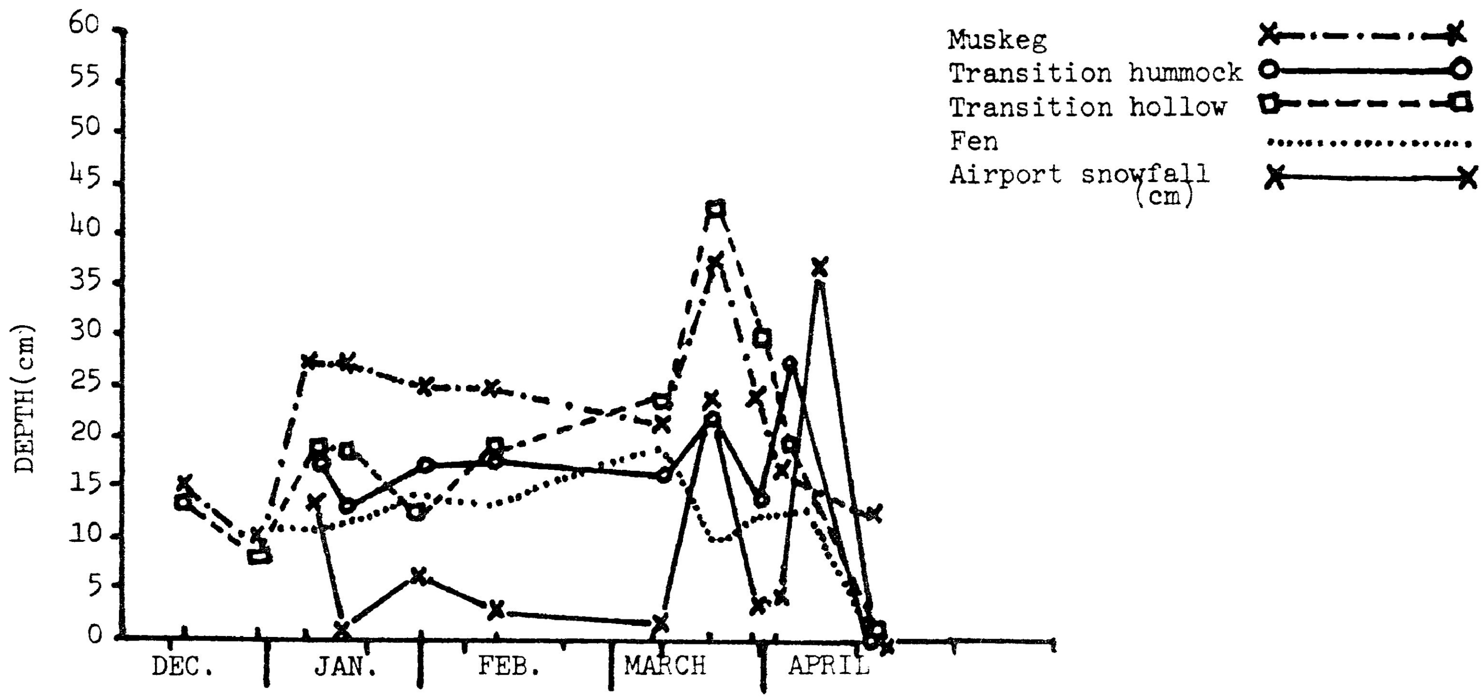
Snow depth was greatest in muskeg and least in the fen. Transition zone hollows accumulated more snow than hummock tops, the deepest snow encountered was in a hollow (52 cm on March 20, 1978).

The study area was blanketed in snow from December 12, 1977 to April 20, 1978. Snow melted most rapidly in fen and transition sites. However, hollows in the muskeg thawed and froze frequently throughout the months of February, March and April.

(ii) Rainfall within the study area and at Thunder Bay Airport

Rainfall was measured in the eastern transition zone of the study area. Table R-87 and Graph R-88 compare rainfall for one week periods from May 19 to November 7, 1978 both in the study area and at the Airport.

Total rainfall from May 19 through November 7 in the study area was 322.2 mm and at the Airport 330.7 mm. The difference between the two sites is 8.5 mm. Because the instrument used at the Airport was read daily and the raingauge in the study area was read weekly differences between rainfall at the two sites can probably be accounted for by evaporation from the raingauge between readings in the study area.

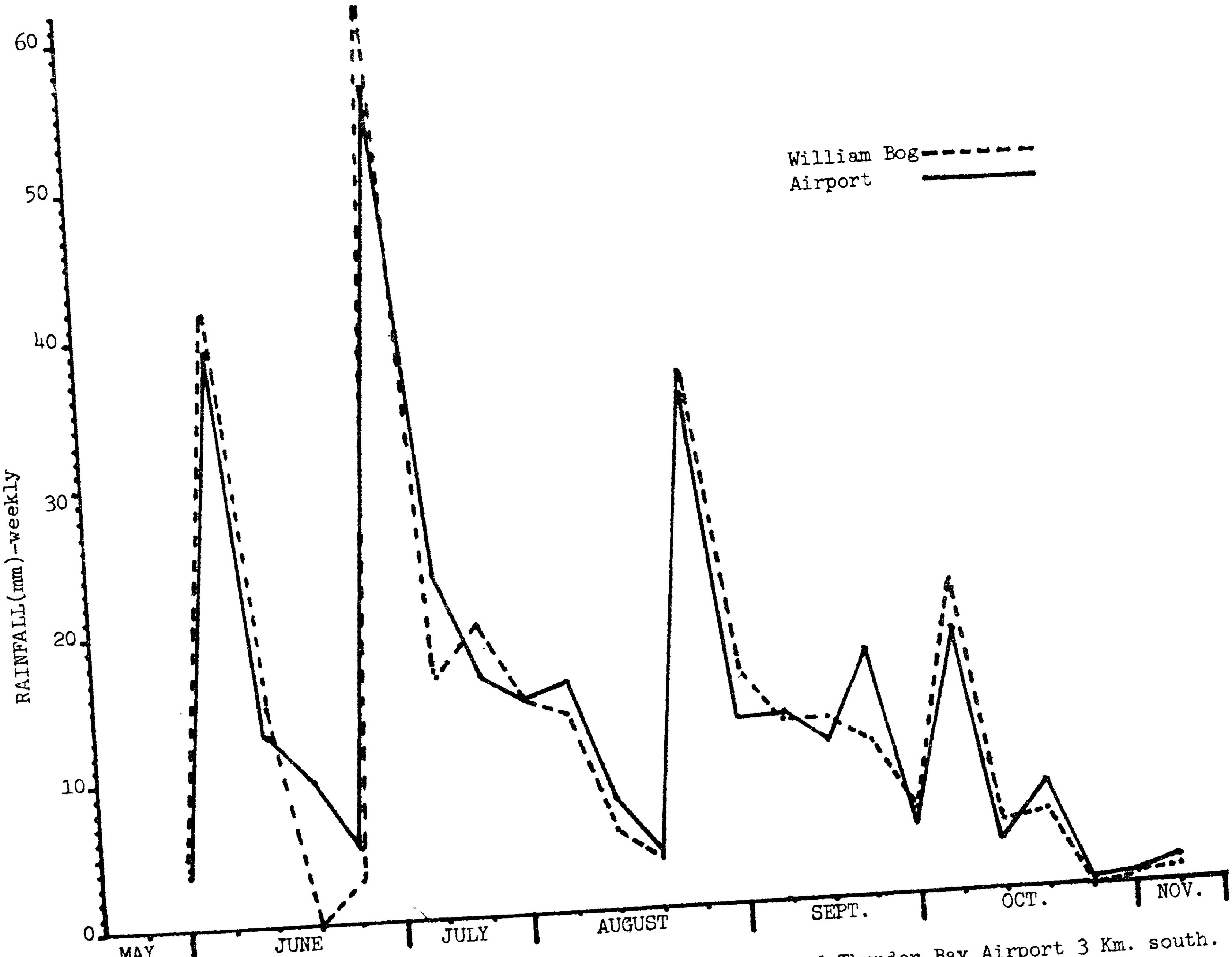


GRAPH R-86. Mean snow depth in muskeg, transition, and fen sites in the study area and weekly snowfall at Thunder Bay Airport (Dec. 12/77-April, 20/78).

Table R-87 1978 Rainfall (mm) Study Area and Thunder Bay Airport

(Weekly Totals)

DATE	William Bog mm Precip. (Rainfall)	Thunder Bay Airport (exclusive of final date)
May 19		
May 25	4.1	3.6
June 2	41.4	39.1
June 8	14.9	12.9
June 15	0	9.8
June 23	2.7	5.0
June 30	61.8	56.3
July 8	16.2	23.4
July 17	19.7	16.2
July 25	14.5	14.4
Aug. 1	13.4	15.6
Aug. 7	5.4	7.6
Aug. 14	3.3	3.7
Aug. 21	36.0	34.5
Aug. 28	15.8	12.3
Sept. 5	12.2	12.6
Sept. 11	12.2	10.8
Sept. 18	10.5	16.7
Sept. 25	5.8	4.9
Oct. 3	21.0	17.9
Oct. 9	4.6	3.6
Oct. 16	5.2	7.2
Oct. 23	0	0.2
Oct. 30	0.6	0.4
Nov. 7	0.9	1.6
Nov. 14		
	froze	
(not including Nov. 14)	322.2	330.7



GRAPH R-88. weekly rainfall at the study area and Thunder Bay Airport 3 Km. south.

(iii) % Relative humidity in muskeg, transition and fen sites

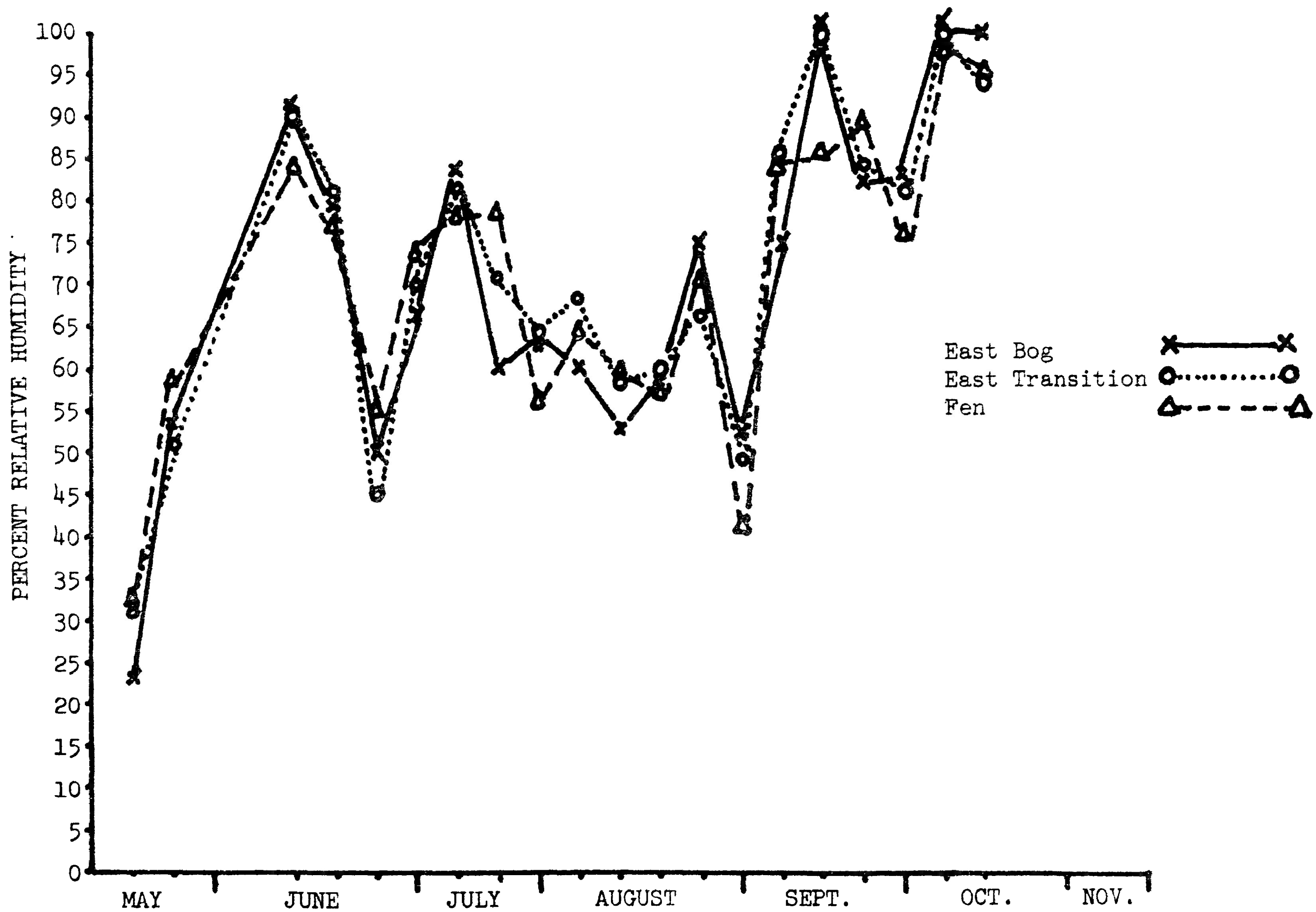
Per cent humidity measured in three sites within the study area is presented in Graph R-89. There were no significant differences ($p \leq 0.05$) in relative humidity between muskeg, transition and fen sites. Readings for the fen were slightly lower than those of other sites.

d) Water and soil level fluctuations

Fluctuations in the water table of muskeg, transition, and fen sites was monitored for 28 weeks (from May 29, 1978 - November 14, 1978) (see Methods II-d). Changes in each level from week to week in each site and in the peat mat are illustrated in graphs R-91 through R-94. Precipitation during the period of observation was included on each graph. Data is outlined in Table R-90.

Muskeg

Muskeg water table levels exhibited large weekly changes during June and July 1978. After 60.5 mm of rainfall from June 23-30, the water table rose 15 mm then fell steadily each week until September 11. The sharpest drop in water level came during the week of July 17-25. After September 11 the water table fluctuated upward with increased rainfall and then fell steadily until freeze up November 14. There appeared to be, no statistically significant relationship between rainfall and muskeg water table fluctuations.



GRAPH R-89.Percent relative humidity in muskeg,transition,and fen sites in the study area(May 18- Oct.30,1978).

Transition

Levels in the transition zone increased 30 mm after 60.5 mm of rainfall from June 23-30. After that time the water table fell steadily until the week of August 21-28. Through September the water table fluctuated with precipitation then fell steadily after October 16 as precipitation dwindled. However, the relationship was not statistically significant.

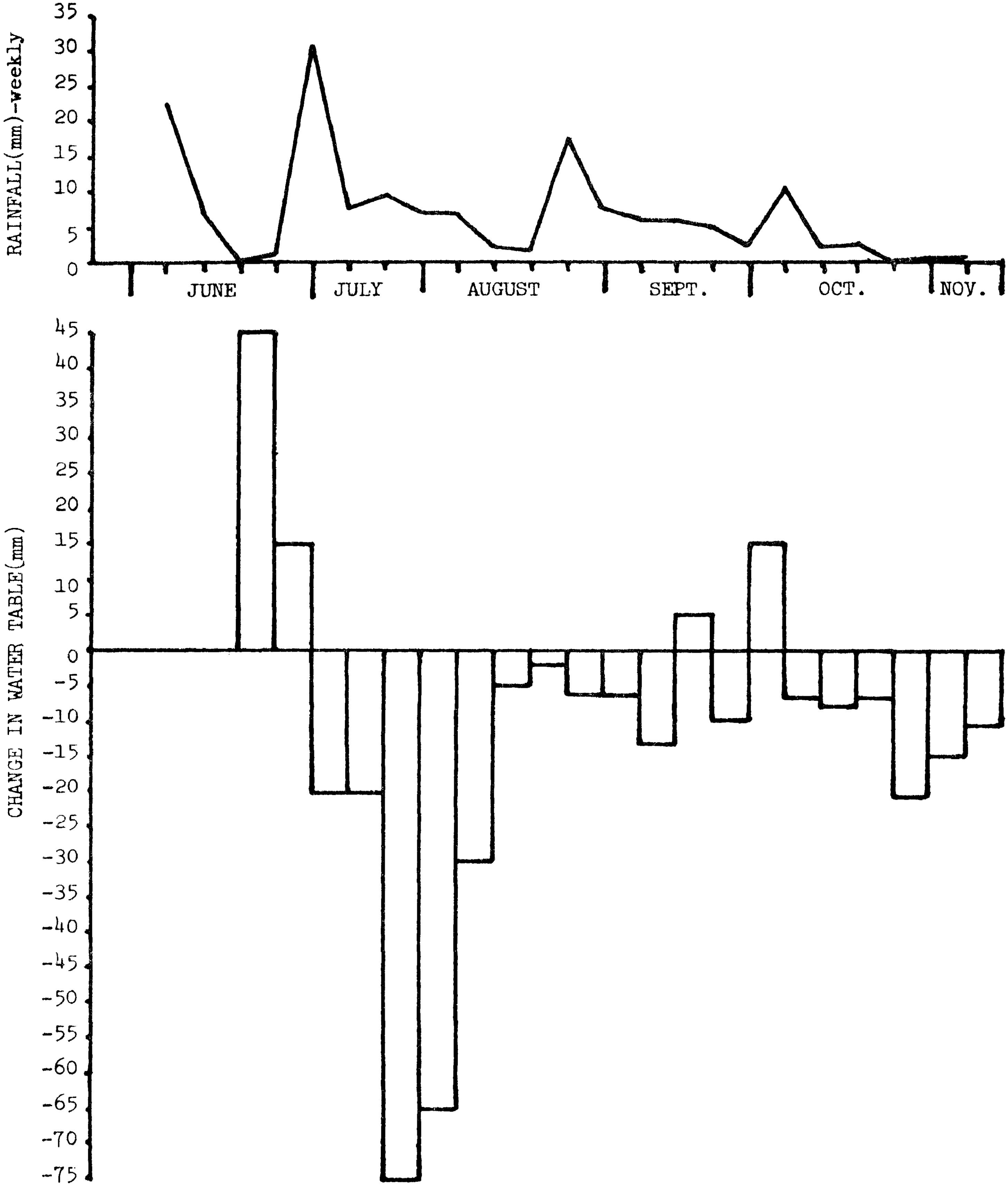
Fen

Water table level in the fen rose 60 mm after 60.5 mm of rainfall from June 23-30. Levels fell steadily until August 28. From that time on the water table fluctuated with rainfall until October 30 when ice formation rendered measurements inaccurate. Once again, the relationship between water table level and rainfall was not statistically significant.

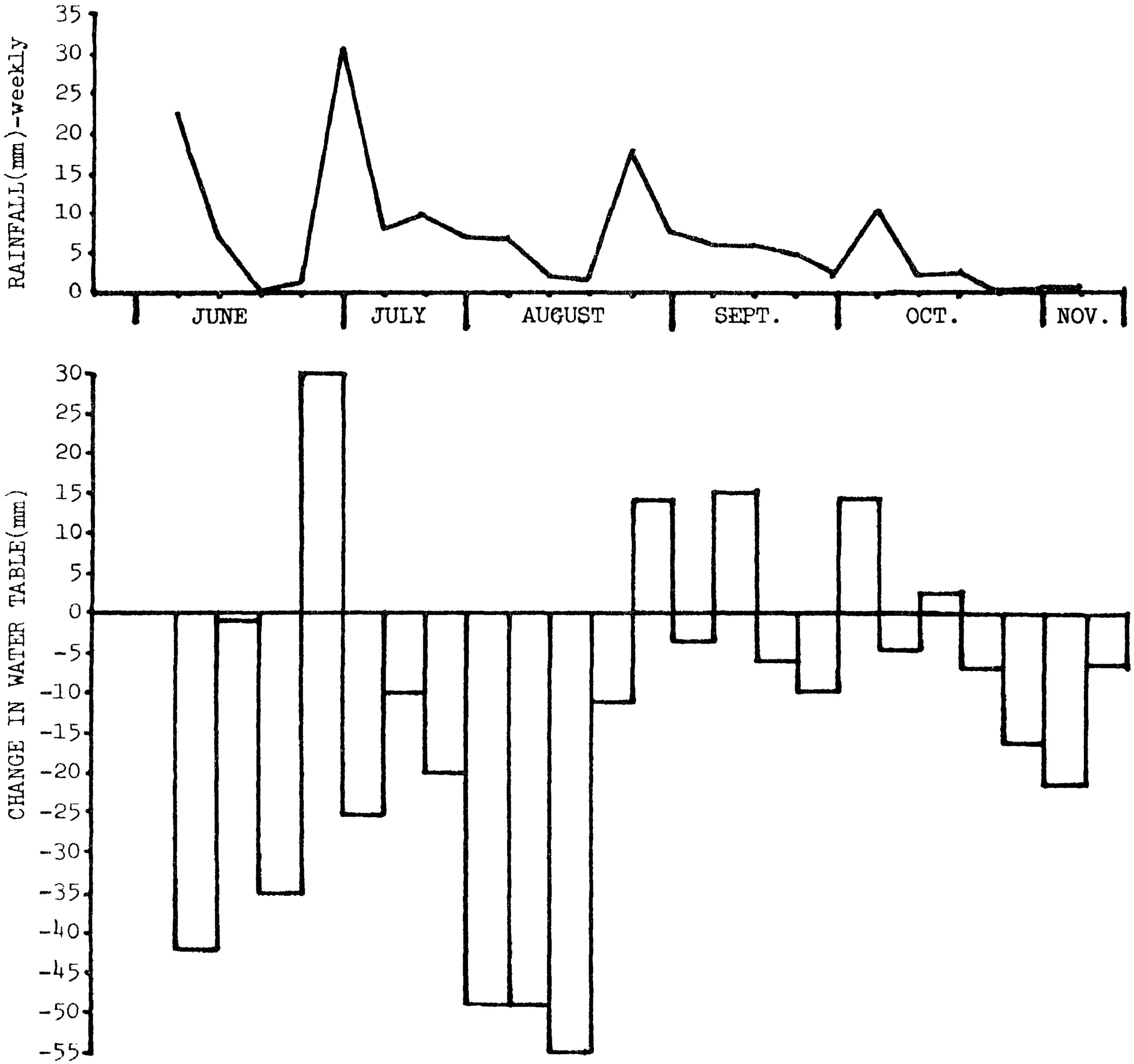
Continued on page 187.

Table R-90 Weekly rainfall, change in water table level and peat mat fluctuation.

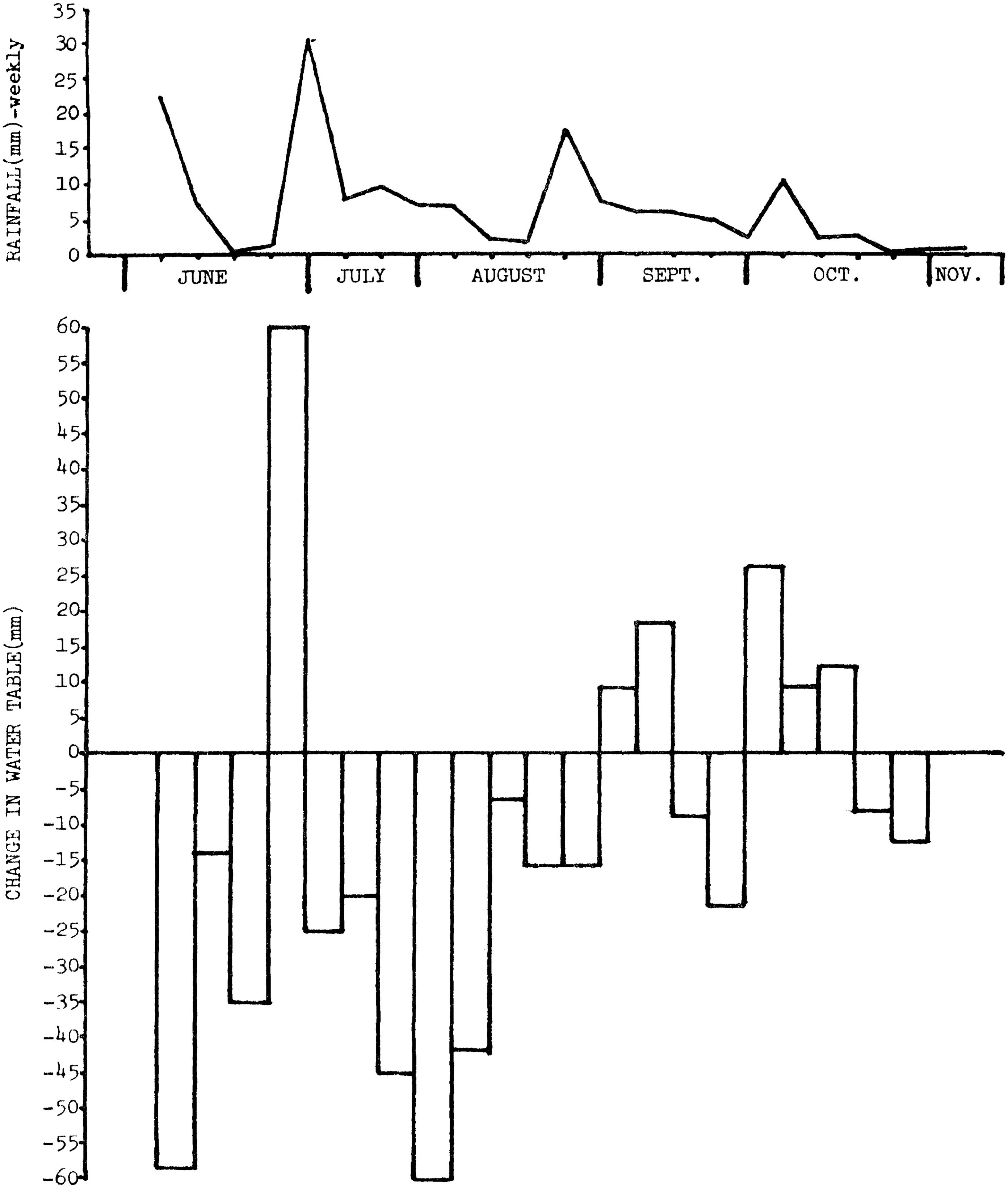
			Change in level		
	Rainfall (mm)	MUSKEG mm	TRANSITION mm	FEN mm	PEAT MAT
1978 May 19					
25	4.1				
June 2	41.4		-	-	-
8	14.9		-42	-58	-20
15	0	-	- 1	-14	-15
23	2.7	+45	-35	-35	+10
30	61.8	+15	30	+60	-20
July 8	16.2	-20	-25	-25	-10
17	19.7	-20	-10	-20	0
25	14.5	-15	-20	-45	+ 5
Aug. 1	13.4	-65	-49	-60	0
7	5.4	-30	-49	-41	0
14	3.3	- 5	-55	- 6	+ 8
21	36.0	-2.5	-11	-16	-13
28	15.8	-6.0	+14	-16	+ 8
Sept. 5	12.2	-6.0	- 4	+ 9	-34
11	12.2	-13	+15	+18	0
18	10.5	+ 5	- 6	- 8	+2.5
25	5.8	0	-10	-21	+ 6
Oct. 3	21.0	+15	+14	+26	- 9
9	4.6	- 6	- 5	+ 9	-13
16	5.2	- 7	2.5	+12	+ 6
23	0	- 6	- 7	+ 7	-12
30	0.6	-21	-17	-12	+ 2
Nov. 7	0.9	-15	-22	-	-



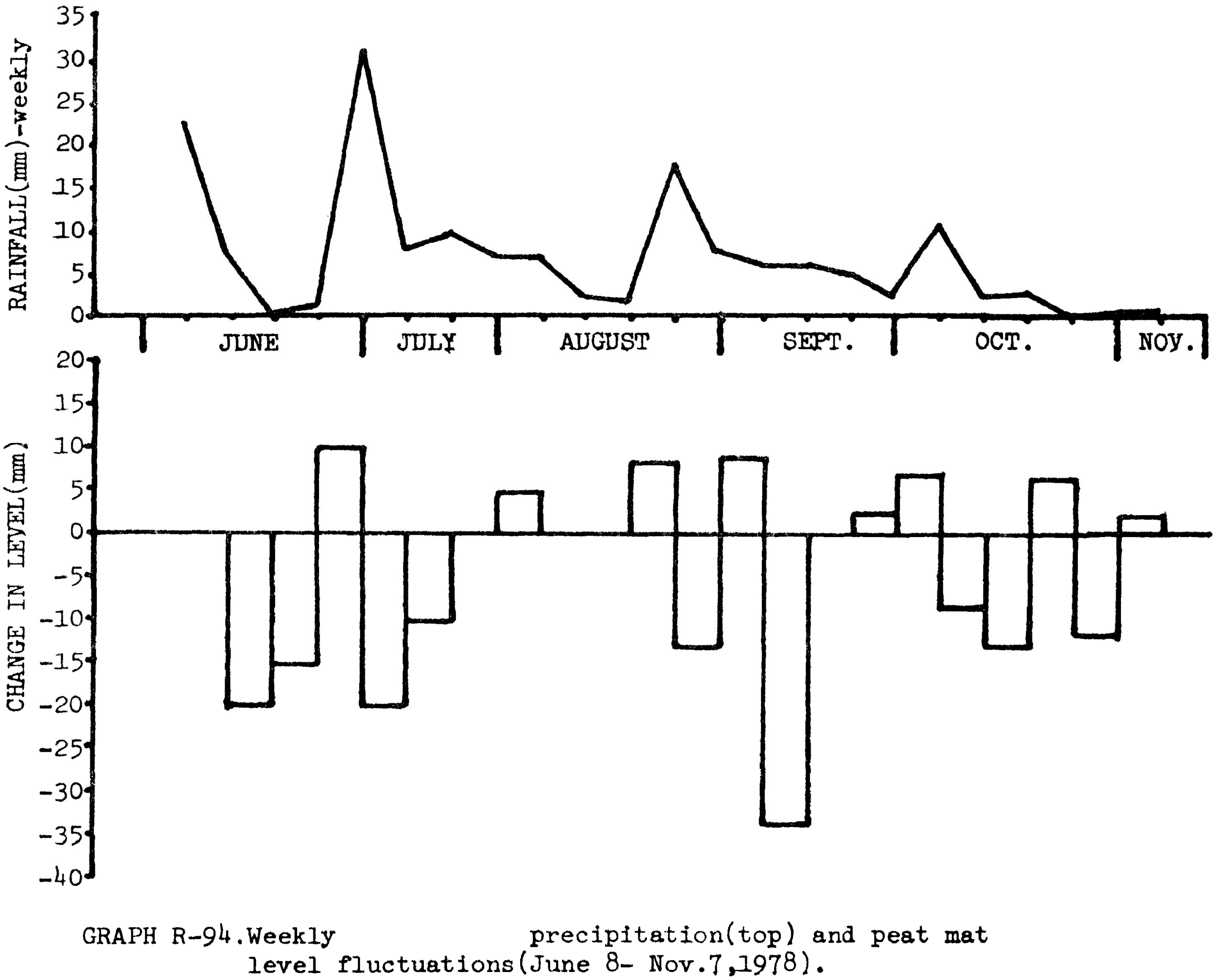
GRAPH R-91.Weekly precipitation(top) and muskeg water table fluctuations in the study area(June 24- Nov.14,1978).



GRAPH R-92. Weekly precipitation(top) and transition zone water table fluctuations in the study area(June 8- Nov.14,1978).



GRAPH R-93. Weekly precipitation(top) and fen water table fluctuations(June 2- Oct. 30,1978).



GRAPH R-94. Weekly precipitation(top) and peat mat level fluctuations(June 8- Nov.7,1978).

In summary, water table fluctuations were greatest in the fen and less in the muskeg and transition. Fluctuations appeared to be related to rainfall or lack of rainfall most noticably in June, September and October. Water levels fell in all sites during July and August. However, these relationships were not statistically significant.

Peat Mat

The peat mat fluctuated with less amplitude than the water table. The mat rose with increased precipitation during the week of June 23-30 and from that time dropped or exhibits no change until the week of July 25 when it rose 5 mm. During the next two weeks the mat's level stayed constant. After August 14 mat fluctuations seem to be related to rainfall or lack of rainfall, but not with statistical significance.

e) Water and soil characteristics

Chemical and physical characteristics of water and soil samples taken from quadrats 1-100 (transects A-G) were measured in the field and laboratory. Mean values, standard deviations and ranges for quadrats falling in subjectively classified muskeg, transition and fen sites, east, north and west of the fen's centre are reported in Tables R-95 through R-110.

. Water

(i) Depth to water table

Depth to the water table was measured in each quadrat (1-100). Results were grouped by subjective classification and location in relation to the fen's centre and are documented in Table R-95.

There was no significant difference between depths to water table in east, north and west muskeg sites. The situation was the same in transition and fen samples. Depth to water table varied significantly ($p \leq 0.05$) only between subjectively classified sites (ie. muskeg, transition, fen). The trend between sites was to shallower water tables as you approach the fen.

(ii) pH of water samples

pH readings of water samples taken from 100 quadrats were grouped by subjective classification and location in relation to the fen centre. Mean values are presented in Table R-96.

Muskeg sites varied significantly from one another ($p \leq 0.05$). Eastern muskeg was the most acidic (4.84) and northern muskeg was the least acidic (6.65).

Transition sites also vary significantly from one another. Eastern transition was the most acidic (5.13) and northern transition was the least acidic (6.75).

Eastern fen samples were significantly different from northern and western fen samples. Eastern fen water was somewhat acidic (5.58) while northern and western fen waters, which do not differ significantly, approach neutrality.

Table R-95

DEPTH TO WATER TABLE (cm)

LOCATION (in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	20.6cm C 33.0 cm 8.92	mean range S.D.	16.06cm ABC 26.0cm 9.24	mean range S.D.	21.12cm C 30.0cm 5.79	19.28 cm
TRANSITION	mean range S.D.	16.2cm BC 32.0cm 8.97	mean range S.D.	7.25cm AB 14.0cm 4.17	mean range S.D.	9.8cm ABC 26.0cm 4.84	11.1 cm
FEN	mean range S.D.	3.9cm A 25.0 cm 9.3	mean range S.D.	5.66cm AB 20.0 cm 8.9	mean range S.D.	3.9cm A 15.0cm 6.4	4.5 cm
MEAN TOTAL		13.58 cm		9.7 cm		11.6 cm	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

Example: East Muskeg is significantly different from East Fen but, not significantly different from East Transition.

North Muskeg is not significantly different from North transition and North Fen

West Muskeg is significantly different from West Fen, but, not West Transition.

None of the Muskeg sites differ significantly from one another.

None of the Transition sites differ significantly from one another.

None of the Fen sites differ significantly from one another.

Table R-96

pH OF WATER SAMPLES (June 1978)

		EAST		NORTH		WEST	MEAN TOTAL
MUSKEG	mean	4.84^{A}	mean	6.65^{C}	mean	6.23^{B}	5.90
	range	0.4	range	0.4	range	1.1	
	S.D.	0.13	S.D.	0.11	S.D.	0.33	
TRANSITION	mean	5.13^{A}	mean	6.26^{B}	mean	6.75^{C}	6.01
	range	1.0	range	1.1	range	0.7	
	S.D.	0.32	S.D.	0.39	S.D.	0.24	
FEN	mean	5.58^{D}	mean	6.40^{C}	mean	6.74^{C}	6.24
	range	0.6	range	0.9	range	0.5	
	S.D.	0.21	S.D.	0.4	S.D.	0.18	
MEAN TOTAL		5.20		6.43		6.57	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See table R-95 for detailed expla nation of how to interpret significance between sites.

Water pH gradients from muskeg to fen were evident on the east side. Readings increased towards the fen, although statistically, only the fen water's pH was significantly different from muskeg and transition. pH readings from the north side of the fen exhibited no gradient from muskeg to fen. Western pH readings demonstrated a gradient from muskeg to transition where pH values increased from 6.23 to 6.75, then stayed uniform between transition and fen.

Water sample pH was similar to soil sample pH's in all sites and locations.

(iii) Calcium content of water samples

Calcium ion (Ca^{++}_{ppm}) concentration in water samples from 100 quadrats was measured in the Lakehead University Science Instrumentation Laboratory. Results were grouped by subjective classification of quadrats and location in relation to the fen. Group means are reported in Table R-97.

Calcium ion concentrations do not differ significantly $(p \leq 0.05)$ from muskeg to fen in neither eastern nor northern locations within the study area. However, there was a non-significant gradient from low (4.09 ppm) to higher (11.68 ppm) concentrations of calcium from muskeg to fen on the east side. Such a gradient was not evident on the north side, calcium concentration was uniform from muskeg to fen. A significant difference in calcium concentration existed between western muskeg and transition sites. A gradient between muskeg (10.61 ppm), transition (20.40 ppm) and fen (23.69), sites on the west side, was evident. Calcium ion concentration increased towards the fen.

Table R-97

CALCIUM CONTENT (ppm) OF WATER SAMPLES

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	4.09ppm[A] 2.1 0.68	mean range S.D.	14.96 ppm[BC] 1.02 1.02	mean range S.D.	10.61ppm[AB] 13.8 4.68	9.89 ppm
TRANSITION	mean range S.D.	8.97ppm[AB] 13.6 4.54	mean range S.D.	14.98ppm[BC] 6.3 1.37	mean range S.D.	20.40ppm[CD] 2.96 7.73	14.78 ppm
FEN	mean range S.D.	11.68ppm[AB] 17.0 5.88	mean range S.D.	15.27ppm[BCD] 8.7 3.05	mean range S.D.	23.69ppm[D] 33.5 10.79	17.31 ppm
MEAN TOTAL		8.25 ppm		15.07 ppm		14.9 ppm	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See Table R-95 for expla nation of how to interpret significance levels between sites.

Table R-98

CONDUCTANCE OF WATER SAMPLES (micromhos/cm at 20°C) June 1978

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	55.81 A 20.0 6.79	mean range S.D.	150.12 BC 36.0 12.26	mean range S.D.	65.25 A 85.0 28.03	90.39
TRANSITION	mean range S.D.	75.86 A 74.0 17.02	mean range S.D.	131.38 B 46.0 15.52	mean range S.D.	145.5 BC 70.0 19.97	117.58
FEN	mean range S.D.	112.57 B 62.0 21.47	mean range S.D.	144.66 BC 14.0 5.28	mean range S.D.	164.3 C 147.0 48.27	140.51
MEAN TOTAL		81.41		142.05		125.02	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See Table R-95 for expla nation of how to interpret significance levels between sites.

Table R-99

NOVEMBER (1978) WATER SAMPLE CONDUCTANCE READINGS (micromhos/cm at 20^{0}C)

	NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	177.2[A] 29 11.987	mean range S.D.	119.6[BF] 61 25.696	148.4
TRANSITION	mean range S.D.	157.4[AD] 36.0 17.23	mean range S.D.	143.0[BCD] 77.0 28.86	150.2
FEN	mean range S.D.	129.4[BE] 54 14.32	mean range S.D.	156.6[AC] 36 14.91	143.0
MEAN TOTAL		154.67		139.73	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See table R-95 for expla nation of how to interpret significance levels between sites.

Calcium ion concentration increased from east through north to west in transition and fen sites, concentrations were significantly different between eastern and western locations, northern locations were intermediate.

(iv) Conductance of water samples

Water samples from quadrats 1-100 were tested for conductance. Mean readings were given in micromhos/cm and grouped by location and subjective classification of quadrats in Table R-98.

Conductance of water samples increased along the gradient from muskeg to fen in eastern and western locations. Differences between sites were significant only between transition and fen on the east side and muskeg and transition on the west side. Samples from northern locations exhibited no gradient from muskeg to fen.

Transition and fen sites presented a gradient in water sample conductance values which ran from low to higher going east through north to the west side of the fen. Muskeg sites did not exhibit such a gradient.

Table R-100 Conductance of water samples (micromhos/cm) at 20°C in June and November 1978

	NORTH		WEST	
	June	Nov	June	Nov
MUSKEG	150.12	177.2	65.25	119.6
TRANSITION	131.38	157.4	145.5	143.0
FEN	144.66	129.4	164.3	156.6

During June sampling of transects C and D excessive rainfall introduced some doubt concerning the validity of conductance values from water samples. Consequently, transects D and E were resampled after a period of low rainfall in November. Results of readings from 30 water samples are presented in Table R-99.

November conductance values differed significantly ($p \leq 0.05$) from June values in only one location, western muskeg. Conductance values were much lower in June (62.25 micromhos/cm) than in November (119.6 micromhos/cm). The gradient in conductance values from low to high, in west side samples, was maintained from June to November (see Table R-100).

A large amount of rainfall appeared to reduce conductance values slightly in all but fen sites.

2. Soil

(v) Soil pH

Soil pH was measured in 100 samples of moist peat during June and July 1978. Results were entered in Table R-101.

When mean pH values were compared between sites east, north and west of the fen, northern and western sites did not differ significantly from one another. Although, peat was slightly more basic (6.67) in northern muskeg and western transition (6.61) than in other northern and western samples. Eastern sites were more acidic in muskeg (4.92) and transition (5.26) than in northern and western samples. Eastern fen samples were more acidic (5.68) than western fen samples (6.38).

Table R-101

SOIL pH (JUNE 1978)

LOCATION (in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	4.92^{A} 0.68 0.22	mean range S.D.	6.67^{D} 0.59 0.20	mean range S.D.	6.37^{D} 0.58 0.18	5.99
TRANSITION	mean range S.D.	5.26^{AB} 0.95 0.25	mean range S.D.	6.19^{D*} 1.43 0.46	mean range S.D.	6.61^{D} 1.03 0.30	6.02
FEN	mean range S.D.	5.68^{BC} 0.70 0.30	mean range S.D.	6.15^{CD*} 1.28 0.50	mean range S.D.	6.38^{D} 1.05 0.23	6.07
MEAN TOTAL		5.29		6.34		6.45	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$ (see Table R-9

Means followed by * are significantly different at $p \leq 0.001$ from November readings taken at the same site.

Table R-102

SOIL pH (NOVEMBER 1978)

LOCATION(in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean	4.64[A]	mean	6.58[C]	mean	6.07[B]	5.76
	range	0.70	range	1.20	range	1.15	
	S.D.	0.27	S.D.	0.47	S.D.	0.33	
TRANSITION	mean	4.84[A]	mean	6.77[C*]	mean	6.21[D]	5.94
	range	0.65	range	1.03	range	1.45	
	S.D.	0.48	S.D.	0.41	S.D.	0.46	
FEN	mean	5.77[B]	mean	6.56[C*]	mean	6.65[C]	6.32
	range	0.95	range	1.47	range	1.15	
	S.D.	0.48	S.D.	0.41	S.D.	0.38	
MEAN TOTAL		5.08		6.64		6.31	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$ (see Table R-95)

Means followed by * are significantly different at $p \leq 0.001$ from June readings taken at the same site.

Table R-103 Mean soil pH in June and November

LOCATION	EAST		NORTH		WEST	
	June	Nov.	June	Nov.	June	Nov.
MUSKEG	4.92	4.64	6.67	6.58	6.37	6.07
TRANSITION	5.26	4.84	6.17*	6.77*	6.61	6.21
FEN	5.68	5.77	6.15*	6.56*	6.38	6.65

* means followed by * are significantly different at $p \leq 0.001$

A gradient from acidic to basic, approaching the fen, was evident on the east side only. Graph R-104 illustrates individual pH readings as a function of distance along transects A-F.

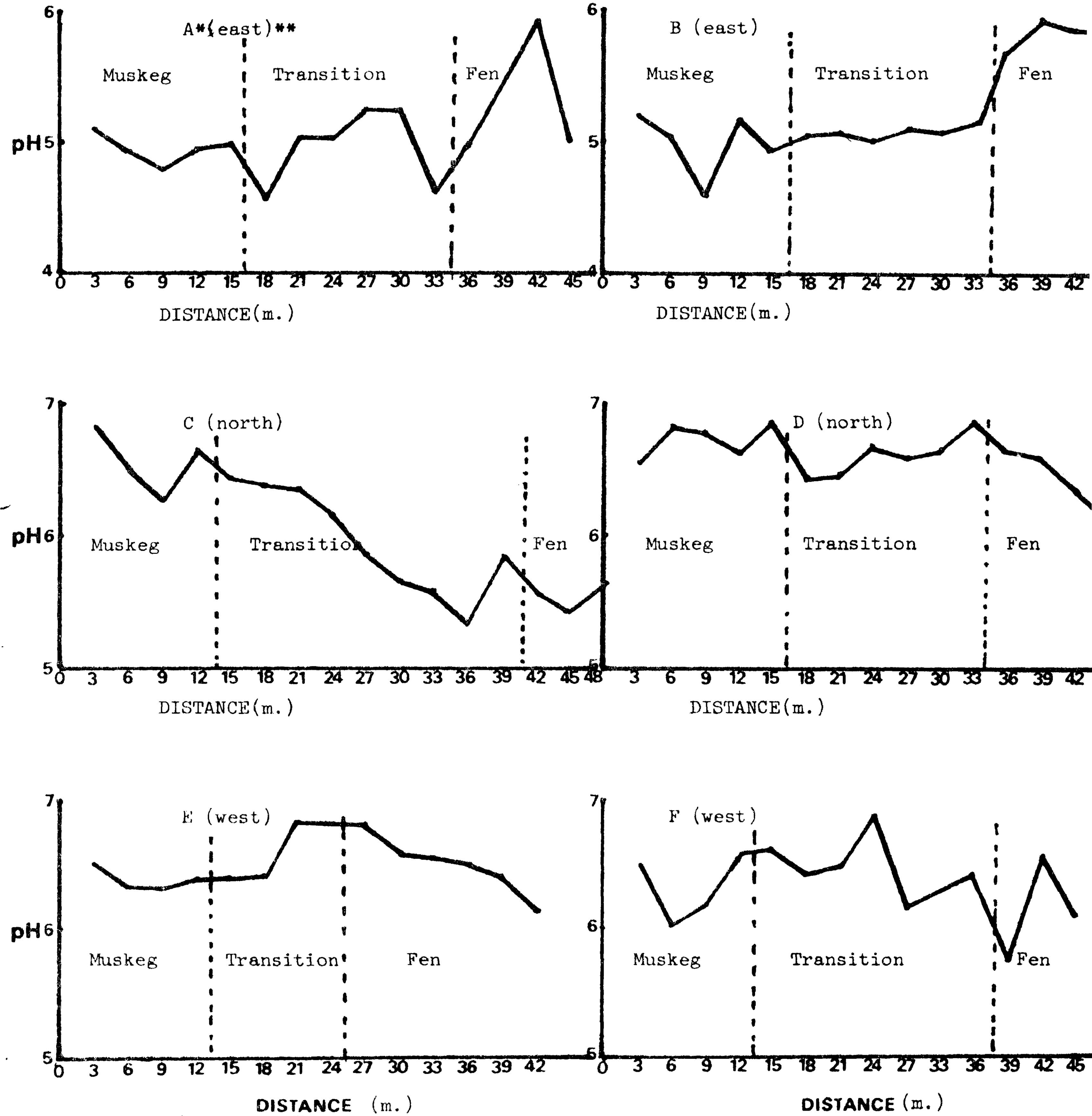
While sampling transects C and D 63.5 mm of rain fell over a two day period. Uniform pH values were suspect due to possible flooding of muskeg and transition sites. Consequently, transects B, C, D, E and F were resampled for soil pH on November 10, 1978 after only 1.5 mm of rainfall over a two week period and flooding effects, consequently, minimized.

Results of November 1978 peat pH values are presented in Table R-102. Although November readings were not as uniform as June readings in sites north and west of the fen, they were still significantly different from east side sites. The only exception was west side muskeg (6.07) where pH values were very similar to eastern fen values (5.77). November pH readings were similar in all sites north of the fen.

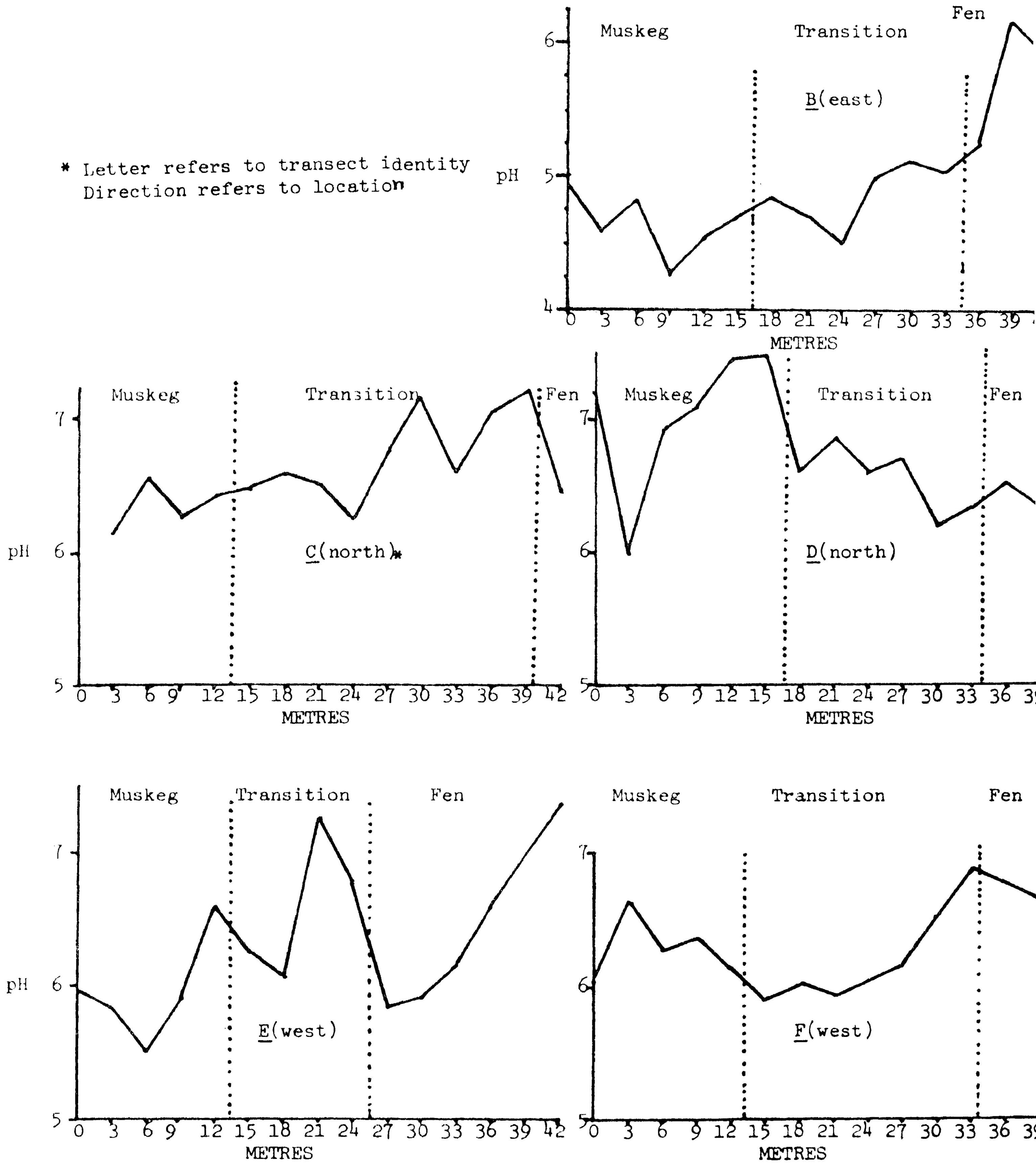
Gradients in pH from muskeg to fen were evident in east and west side samples only. Graph R-105 depicts pH readings as a function of distance along the transect for November samples in transects B, C, D, E, and F.

When comparing June and November pH values at $p \leq 0.001$ the only sites which differ significantly were the western transition and fen. November samples were more basic (transition 6.77, fen. 6.56) than (transition 6.15, fen 6.19) June samples. The effect of high rainfall over a short period was to lower the peat pH's and reduce the difference in pH between muskeg, transition and fen sites.

* Letter refers to transect identification
** Direction refers to transect origin in relation to fen centre.



GRAPH R-104. June 1978-Peat pH readings along transects running from Muskeg to Fen.



GRAPH R-105.November 1978-Peat pH readings along transects running from Muskeg to Fen.

Table R-105 A

pH, Conductivity (micromhos/cm at 20^{0}C) and Calcium concentration (ppm) of rainwater sample obtained June 30 1978 from rain gauge in the study area.

	pH	conductance (Micromhos/cm at 20^{0}C)	calcium (ppm)
rainwater	6.25	21.0	1.3

(vi) C/N ratio of peat samples

C/N ratios of peat samples were calculated from total carbon and nitrogen data. Results of analysis of 100 samples, grouped by subjective classification and location in relationship to the fen centre, can be found in Table R-106.

C/N ratios in all muskeg sites do not differ significantly, at $p \leq 0.05$, when compared by location in relation to the fen. This was also the case in fen sites. Transition zone C/N ratios differ significantly between the east (55.99) and west (23.45) sides only. West side mean C/N ratio was lower, indicating more total nitrogen in peat samples.

C/N ratios do not differ singificantly between muskeg, transition and fen sites. There was no gradient of C/N ratios, either increasing or decreasing, from muskeg to fen.

(vii) Ammonium and Nitrate content of peat samples

Available nitrogen in the form of ammonium and nitrate ions was measured in 29 peat samples taken from transects A and F. Results are presented in Table R-107 and R-108. There were no significant differences at $p \leq 0.05$ detected between subjectively grouped sites and location in relationship to the fen.

Ammonium content (NH_4^+), in ppm, appeared to be greater in muskeg and fen sites than in transition sites. Nitrate content (NO_3^-) in ppm, was relatively uniform between sites. The lowest value (1.5 ppm) occurred in the eastern transition zone, the highest value (6.1 ppm) was found in the eastern muskeg site.

Table R-106

C/N RATIOS OF PEAT

LOCATION (in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean	46.18 AB	mean	33.25 AB	mean	27.25 A	35.56
	range	45.57	range	17.9	range.	21.83	
	S.D.	13.56	S.D.	4.92	S.D.	6.74	
TRANSITION	mean	55.99 B	mean	35.15 AB	mean	23.45 A	38.20
	range	126.24	range	55.01	range	8.91	
	S.D.	35.01	S.D.	13.09	S.D.	2.77	
FEN	mean	36.15 AB	mean	33.39 AB	mean	28.97 A	32.84
	range	24.62	range	55.01	range	10.36	
	S.D.	9.59	S.D.	2.66	S.D.	10.36	
MEAN TOTAL		46.11		33.93		26.56	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See Table R-95 for expla nation of significance levels between sites.

Table R-107

AMMONIUM CONTENT OF SOIL SAMPLES (TRANSECTS A and F only)

	EAST (A)		WEST (F)	
MUSKEG	mean	122ppm	mean	104.5ppm
	range	123ppm	range	124 ppm
	S.D.	44.85	S.D.	51.41
TRANSITION	mean	94.17ppm	mean	62.0ppm
	range	43ppm	range	14.58ppm
	S.D.	15.87	S.D.	32.92
FEN	mean	130.66ppm	mean	103.0ppm
	range	70ppm	range	66 ppm
	S.D.	35.23	S.D.	32.92

Table R-108

NITRATE CONTENT OF SOIL SAMPLES (TRANSECTS A and F only)

	EAST (A)		WEST (F)	
MUSKEG	mean	6.1ppm	mean	4.2ppm
	range	31.0ppm	range	11.0ppm
	S.D.	12.65	S.D.	5.2
TRANSITION	mean	1.5ppm	mean	5.1ppm
	range	3.0ppm	range	17.0 ppm
	S.D.	1.22	S.D.	6.4
FEN	mean	2.66ppm	mean	3.75ppm
	range	5.0ppm	range	4.0ppm
	S.D.	2.8	S.D.	1.89

NO SIGNIFICANT DIFFERENCES BETWEEN MEANS WERE DETECTED AT $p \leq 0.05$

There was no gradient in available nitrogen values from muskeg to fen.

(viii) Per cent loss-on-ignition of peat

Loss-on-ignition of peat samples from 100 quadrats was determined in the laboratory. Results are presented in Table R-109. Values were grouped by subjective classification and location in relationship to the fen's centre.

Per cent loss-on-ignition of peat samples from muskeg sites did not differ significantly ($p \leq 0.05$) with location. Transition sites differed significantly from east to west. Western transition zone peat lost less upon ignition (67.52%) than did eastern transition peat (81.07%). Fen peat loss-on-ignition differed significantly between eastern and western sites. Western fen peat (15.01%) lost less when ignited than eastern fen peat (79.68%).

Although, there was no statistically significant change in loss-on-ignition from muskeg to fen in each location, there was a slight gradient. Muskeg site peat samples lost the most material upon ignition, transition sites lost an intermediate amount and fen samples lost the least material upon ignition.

(ix) von Post humification of peat

Humification of peat samples was assessed in the field using the von Post scale. Results from 100 quadrats grouped by subjective classification and location in relation to the fen's centre are shown in Table R-110.

Table R-109

PERCENT LOSS ON IGNITION OF PEAT SAMPLES

LOCATION (in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	86.81%[C] 12.01% 4.24	mean range S.D.	78.34%[ABC] 26.77% 8.83	mean range S.D.	75.05%[ABC] 44.76 13.36	80.66%
TRANSITION	mean range S.D.	81.07%[C] 20.3% 6.15	mean range S.D.	75.77%[ABC] 40.9% 9.9	mean range S.D.	67.52[AB] 27.04 10.88	74.80%
FEN	mean range S.D.	79.68%[BC] 24.3% 8.54	mean range S.D.	76.00%[ABC] 22.67% 6.8	mean range S.D.	65.01[A] 27.04% 10.04	73.60%
MEAN TOTAL		82.50%		76.70%		69.20%	

Means followed by the same letter DO NOT differ significantly at $p \leq 0.05$

See Table R-95 for explanation of significance levels between sites.

Table R-110

VONPOST HUMIFICATION OF PEAT

LOCATION (in relation to the fen)

	EAST		NORTH		WEST		MEAN TOTAL
MUSKEG	mean range S.D.	2.9 3 0.94	mean range S.D.	3.5 3 1.1	mean range S.D.	3.6 4 1.4	3.3
TRANSITION	mean range S.D.	3.1 4 1.22	mean range S.D.	3.9 2 0.66	mean range S.D.	4.0 3 0.94	3.6
FEN	mean range S.D.	3.7 3 1.1	mean range S.D.	4.2 2 0.75	mean range S.D.	4.4 3 1.58	4.1
MEAN TOTAL		3.2		3.8		4.0	

No significant differences between means were detected at $p \leq 0.05$

See Table R-95 for explanation of significance levels between sites.

No statistically significant relationships between grouped mean values were detected at $p \leq 0.05$.

Muskeg peat tends to be the least humified in all locations. Eastern muskeg peat (2.9) was less humified than northern or western muskeg peat (3.5, 3.6 respectively). Transition peat was intermediately humified when compared to muskeg and fen peats in all locations. Eastern transition peat was less humified than northern or western transition peat. Fen peat was the most humified in all locations, western fen samples had the highest von Post rating, northern were intermediate and eastern the least humified of the fen samples.

There were two identifiable gradients in humification of peat. The first went from muskeg to fen, fen samples being the most humified. The second gradient ran from east to west, with western samples the most humified. However, these gradients were not statistically significant at $p \leq 0.05$.

3. Relationships between environmental factors

In order to ascertain the degree of interrelationship between measured environmental factors Pearson correlation coefficients were calculated for all possible pairs of factors. Results of this analysis can be found in Table R-111. Environmental factors significantly correlated at $p \leq 0.001$ are summarized in Table R-112.

One group of Factors (Group I) whichwere positively correlated are: pH of soil, pH of water, conductance of water, calcium content of water, von Post humification of peat, and to some degree total N content of the soil. Another group of positively correlated factors (Group II) were loss on ignition, total carbon, total hydrogen and depth to water table. In most cases group I environmental factors were negatively correlated to group II factors. The factors which showed the least correlation to any other factors are ammonium (NH_3^+) and nitrate (NO_3^-).

Table R-111 Pearson correlation coefficients calculated between all measured environmental factors in the study area

factor	number of cases	von Post	pH Soil	% L.O.I.	% C	% H	% N	depth to water table (cm)	pH water	conductance (mmhos at 20°C)	Calcium (ppm)	NH_3^+ (ppm)	NO_3^- (ppm)
von Post	100	1.00	0.32*	-0.449*	-0.402*	-0.433*	-0.299	-0.443*	0.371*	0.438*	0.472*	0.047	0.047
pH soil	100		1.00	-0.443*	-0.223	-0.247	-0.399*	-0.246	0.931*	0.681*	0.562*	-0.388	0.036
% L.I.	100			1.00	0.975*	0.615*	-0.049	0.301	-0.498*	-0.451*	-0.517*	0.246	-0.039
% Carbon	100				1.00	0.923*	0.290	0.408*	-0.327	-0.382*	-0.429*	0.413	0.037
% hydrogen	100					1.00	0.278	0.367*	-0.316	-0.339*	-0.406*	0.413	0.054
% nitrogen	100						1.00	-0.128	0.417*	0.296	0.341*	0.222	0.074
depth to water table	100							1.00	-0.354*	0.509*	-0.412*	-0.147	0.075
pH water	100								1.00	0.776*	0.676*	-0.377	0.071
conductance	100									1.00	0.802*	-0.206	0.055
calcium	99										1.00	-0.118	0.206
NH_3^+	29											1.00	0.056
NO_3^-	29												1.00

* $p \le 0.001$

Table R-112

Groups of positively correlated environmental factors.

GROUP I FACTORS	GROUP II FACTORS
pH soil	Loss on ignition of soil
pH water	Total carbon of soil
Conductance of water	Total hydrogen of soil
Calcium concentration of water	Depth to water table
Total N in soil	

factors within a group are positively correlated ($p \leq 0.001$)

factors between groups are negatively correlated ($p \leq 0.001$)

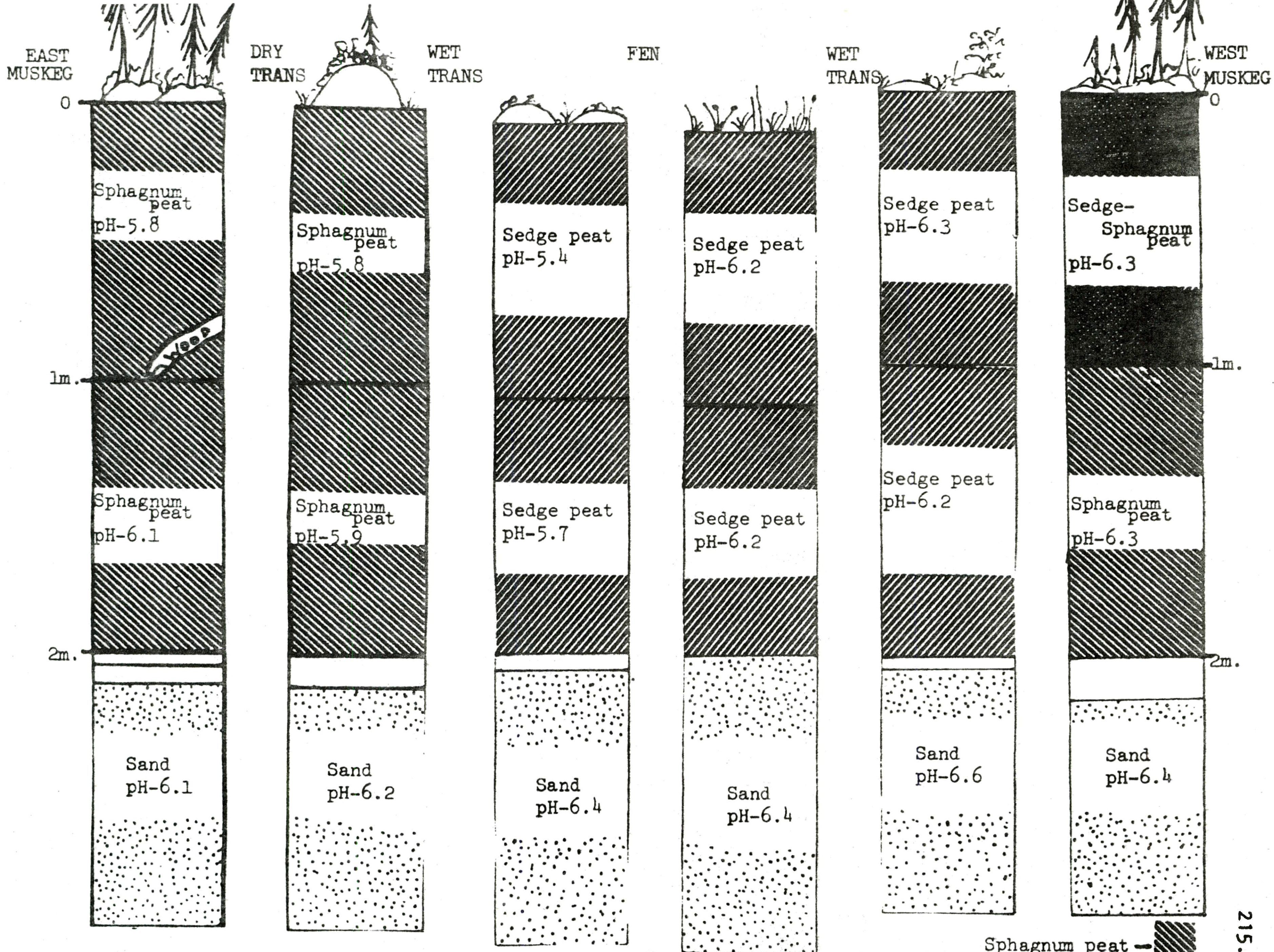
f) Peat stratigraphy

A series of six peat cores were taken along a transect running from east to west across the study area (see Figure M-1). Stratigraphy of the peat deposits underlying the study area, as determined from the peat cores, is illustrated in Figure R-113.

Sands formed the base upon which the peat mat had developed. The pH of the sands varied from the east to the west side. Sands underlying muskeg and transition zones were slightly less basic (6.1 and 6.2 respectively) than sands beneath the fen (6.4), fen sands were slightly less basic than west side transition zone (6.6). West side muskeg was on sands of pH 6.4. The zone between the sand and peat consisted of a compacted mixture of sand and peat. This zone was absent in the wettest part of the fen. The sedge peat mat was probably floating on a layer of water. Cores taken east of the fen were entirely *Sphagnum* peat with a mean pH of 5.9. Cores from the fen were entirely composed of sedge peat with more acidic pH's to the east. West side transition zone consisted of sedge peat with a mean pH of 6.25. West side muskeg was underlain by *Sphagnum* peat at depths greater than one metre. Above one metre the peat was a mixture of *Sphagnum* and sedges.

In transition and fen cores the peat became more humified with depth. Muskeg peat humification remained unchanged, although east side muskeg was less humified than west side muskeg.

There was no indication of a charcoal layer in any of the peat cores removed from the study area.



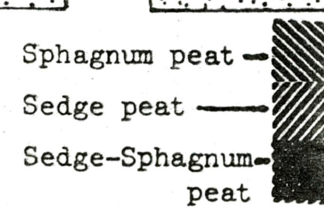


FIGURE R-113. Peat stratigraphy along an East to West transect of the study area including pH of the various strata.

Results

III Vegetation-Environment Relationships

Introduction

It has been demonstrated in the Vegetation section of the results that the floral composition of the study area varied with location in relation to the fen's centre. It followed a continuous gradient from muskeg through transition to fen, as well as from east to north to west. In this section environmental factors are related to vegetation in order to examine any vegetation-environment relationships present in the study area. Environmental factors with a significant effect on vegetation distribution will be identified.

a) Relationships between environmental factors and Bray and Curtis Ordination

Measured environmental factors were plotted on the Bray and Curtis ordination of quadrats in Figures R-116 through R-120. Isobars were drawn around measures falling into arbitrarily defined measurement classes.

(i) Depth to water table

The most obvious environmental factor to be associated with any variation in vegetation was depth to the water table (see Table R-114). Figure R-116 illustrates how depth to the water table varied throughout the ordination. The entire study area falls into (see Table R-115) Jeglum et al's (1974) surface water level category IV (water level from 20 cm above to 20 cm below ground surface) except a very few quadrats which can be classified as Category V (wet - groundwater 20-60 cm beneath ground surface). Depths to water table were

Table R-114 Values of environmental factors plotted on Bray and Curtis ordination

Quadrat	Subjective Classification	Depth to water table (cm)	C/N (c:1)	Soil pH (June)	conductivity (mhos) at 20°C	calcium (ppm)
A-001	E-T	7	107.26	5.25	72	4.0
A-002	E-T	22	142.72	5.25	70	4.4
A-003	E-T	0	36.36	5.08	56	3.8
A-004	E-T	12	48.58	5.10	51	4.0
A-005	E-M	4	71.42	4.52	52	3.3
A-006	E-M	22	42.19	5.00	64	3.6
A-007	E-M	7	25.85	4.98	50	3.7
A-008	E-M	18	62.78	4.78	56	3.3
A-009	E-M	17	42.60	4.95	55	5.4
A-010	E-M	20	54.85	5.05	60	4.0
A-011	E-T	20	51.97	4.65	75	4.1
A-012	E-T	3	37.59	5.00	70	4.6
A-013	E-F	2	30.62	5.25	100	4.3
A-014	E-F	0	-	5.25	78	6.1
A-015	E-F	0	29.87	5.95	130	11.3
B-016	E-M	15	32.63	5.19	48	4.9
B-017	E-M	12	44.29	5.02	56	4.4
B-018	E-M	21	44.43	4.55	62	4.3
B-019	E-M	25	33.33	5.20	68	-
B-020	E-M	30	53.57	4.90	49	4.0
B-021	E-T	15	43.01	5.05	52	8.3
B-022	E-T	25	66.59	5.05	38	5.7
B-023	E-T	21	55.94	5.06	56	4.6
B-024	E-T	7	54.24	5.15	72	5.3
B-025	E-T	35	145.82	5.08	92	5.4
B-026	E-T	10	46.40	5.10	112	8.5
B-027	E-F	0	23.23	5.70	140	15.7
B-028	E-F	0	41.94	5.90	128	9.0
B-029	E-F	25	43.37	5.85	102	14.1
B-030	E-F	0	47.85	5.85	110	21.3

Table R-114 continued

Quadrat	Subjective Classification	Depth to water table (cm)	C/N (c:1)	Soil pH (June)	conductivity (mhos) at 20°C	calcium (ppm)
C-031	N-M	20	29.80	6.85	155	16.2
C-032	N-M	5	32.04	6.50	148	16.3
C-033	N-M	15	32.71	6.28	137	14.6
C-034	N-M	15	35.00	6.70	128	13.8
C-035	N-T	13	25.64	6.40	130	15.8
C-036	N-T	8	27.15	6.38	132	16.0
C-037	N-T	5	24.40	6.39	130	15.4
C-038	N-T	7	27.75	6.20	121	14.6
C-039	N-T	11	71.83	5.80	118	14.9
C-040	N-T	12	40.69	5.72	108	14.1
C-041	N-T	4	33.38	5.62	115	13.7
C-042	N-T	7	36.73	5.42	116	15.7
C-043	N-T	7	56.14	5.80	112	14.9
C-044	N-T	7	39.82	5.55	129	18.7
C-045	N-F	0	30.02	5.42	141	20.3
C-046	N-F	0	32.13	5.70	150	17.2
D-047	N-M	9	25.50	6.52	160	15.9
D-048	N-M	12	36.00	6.85	164	15.6
D-049	N-M	31	43.40	6.80	156	15.1
D-050	N-M	29	30.90	6.70	150	15.1
D-051	N-M	12	33.94	6.87	158	13.3
D-052	N-T	14	16.82	6.40	145	13.9
D-053	N-T	8	28.94	6.48	154	15.2
D-054	N-T	0	31.50	6.72	151	15.7
D-055	N-T	0	35.90	6.60	151	13.9
D-056	N-T	10	31.60	6.68	140	12.4
D-057	N-T	3	34.17	6.85	150	14.9
D-058	N-F	14	34.47	6.70	145	13.7
D-059	N-F	0	36.87	6.60	148	14.6
D-060	N-F	0	35.58	6.30	148	14.2
D-061	N-F	20	31.28	6.20	136	11.6

Table R-114 continued

Quadrat	Subjective Classification	Depth to water table (cm)	C/N (c:1)	Soil pH (June)	conductivity (mhos) at 20°C	calcium (ppm)
E-062	W-M	25	37.03	6.50	50	8.9
E-063	W-M	19	32.83	6.35	15	15.5
E-064	W-M	25	23.64	6.35	80	9.5
E-065	W-M	22	27.70	6.40	65	5.7
E-066	W-T	11	20.78	6.40	100	11.4
E-067	W-T	5	21.47	6.40	145	18.9
E-068	W-T	9	29.69	6.85	138	18.7
E-069	W-T	5	23.92	6.75	150	21.1
E-070	W-F	0	30.33	6.80	160	22.4
E-071	W-F	0	22.79	6.55	140	19.4
E-072	W-F	10	41.80	6.55	129	17.1
E-073	W-F	14	44.64	6.50	130	17.6
E-074	W-F	15	30.80	6.45	122	16.1
E-075	W-F	0	40.62	6.20	115	13.5
F-076	W-M	16	15.20	6.50	100	10.8
F-077	W-M	31	25.97	6.02	42	6.3
F-078	W-M	18	23.91	6.22	85	19.5
F-079	W-M	13	31.74	6.60	85	8.7
F-080	W-T	13	25.51	6.62	132	17.0
F-081	W-T	5	-	6.40	148	17.9
F-082	W-T	11	22.42	6.50	145	17.5
F-083	W-T	10	22.30	6.70	165	20.3
F-084	W-T	8	21.06	6.22	170	141.0
F-085	W-T	21	23.88	7.25	162	20.2
F-086	W-F	0	23.90	6.48	165	20.9
F-087	W-F	0	20.68	5.75	210	23.9
F-088	W-F	0	16.55	6.52	210	39.0
F-089	W-F	0	17.60	6.15	262	47.0
G-090	E-T	19	40.93	5.60	90	13.6
G-091	E-T	26	33.98	5.42	78	11.8
G-092	E-T	14	34.90	5.42	85	14.7
G-093	E-T	17	33.38	5.58	85	14.4
G-094	E-T	10	28.83	5.52	92	16.2
G-095	E-T	19	40.00	5.40	85	14.1
G-096	E-T	5	19.58	5.52	98	17.4
G-097	E-T	21	29.93	5.48	85	12.6
G-098	E-T	22	34.15	5.52	78	10.7
G-099	E-T	12	40.87	5.52	78	9.7
G-100	E-T	32	77.66	5.28	75	8.5

Table R-115

Jeglum *et al.* (1974) Moisture Aeration CLASSES

i) Deep standing water; more than 1 m of water above ground level

ii) Medium depth standing water; 60 cm - 1 m of water above ground level

iii) Shallow standing water; 20 cm - 60 cm of water above ground level

iv) Surface water level; water level from 20 cm above to 20 cm below the ground surface

v) Wet; groundwater level 20 - 60 cm beneath ground surface

vi) Wet mesic (or very moist); groundwater level 60 - 100 cm beneath ground surface.

Jeglum *et al.* (1974) Nutrient-pH CLASSES

* pH ranges are ca. 0.5 units lower if moist peat pH is used (Jeglum, 1971)

i) Very oligotrophic; pH equal to or less than 4.4 (ca. ombrotrophic)

ii) Oligotrophic; pH 4.5 to 5.4 (ca. weakly minerotrophic)

iii) Mesotrophic; pH 5.5 to 6.4

iv) Eutrophic; pH 6.5 to 7.4

v) Very eutrophic; pH 7.5 or higher.

Figures R-116 to R-120 inclusive

Grouped values of environmental measurements (see Table R-114) of soils and groundwater samples taken from quadrats 1 to 100 plotted on Bray and Curtis (1957) ordination of presence/absence floristic data from quadrats 1 to 100.

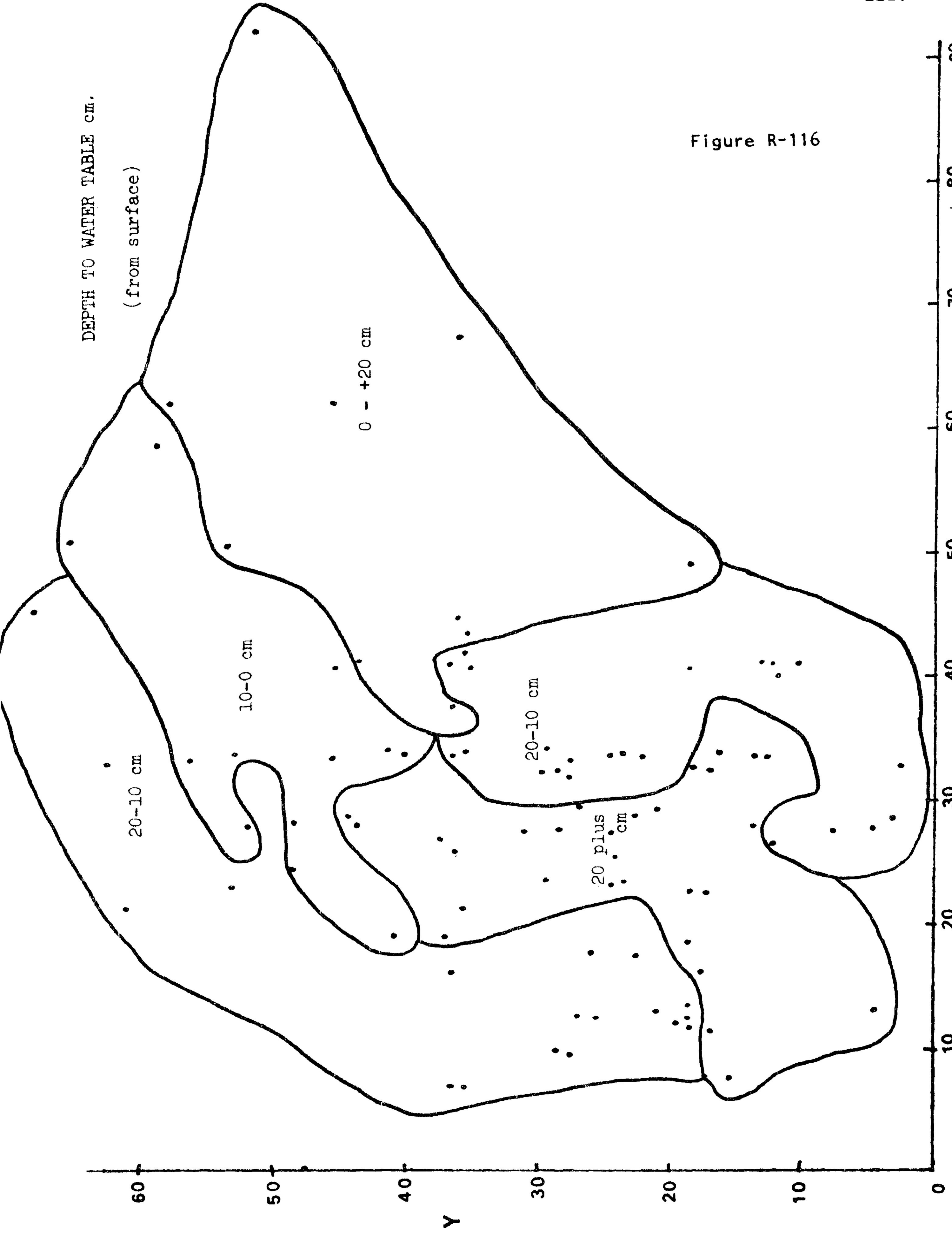

DEPTH TO WATER TABLE cm.
(from surface)
0 - +20 cm
10-0 cm
20-10 cm
20-10 cm
20 plus cm
X
Y
0
10
20
30
40
50
60
70
80
90

Figure R-116

C/N ratios of peat samples

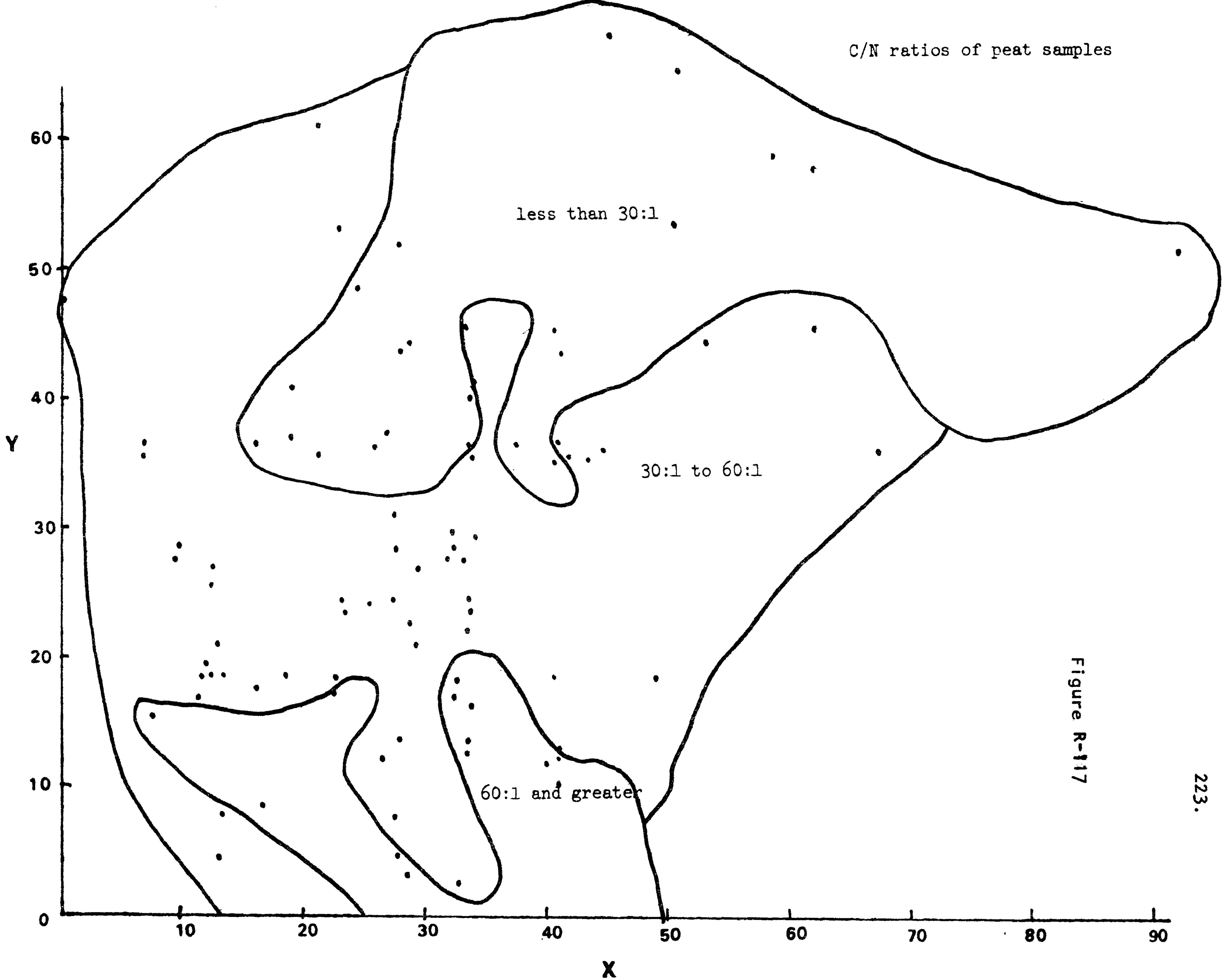


Figure R-117

SOIL pH

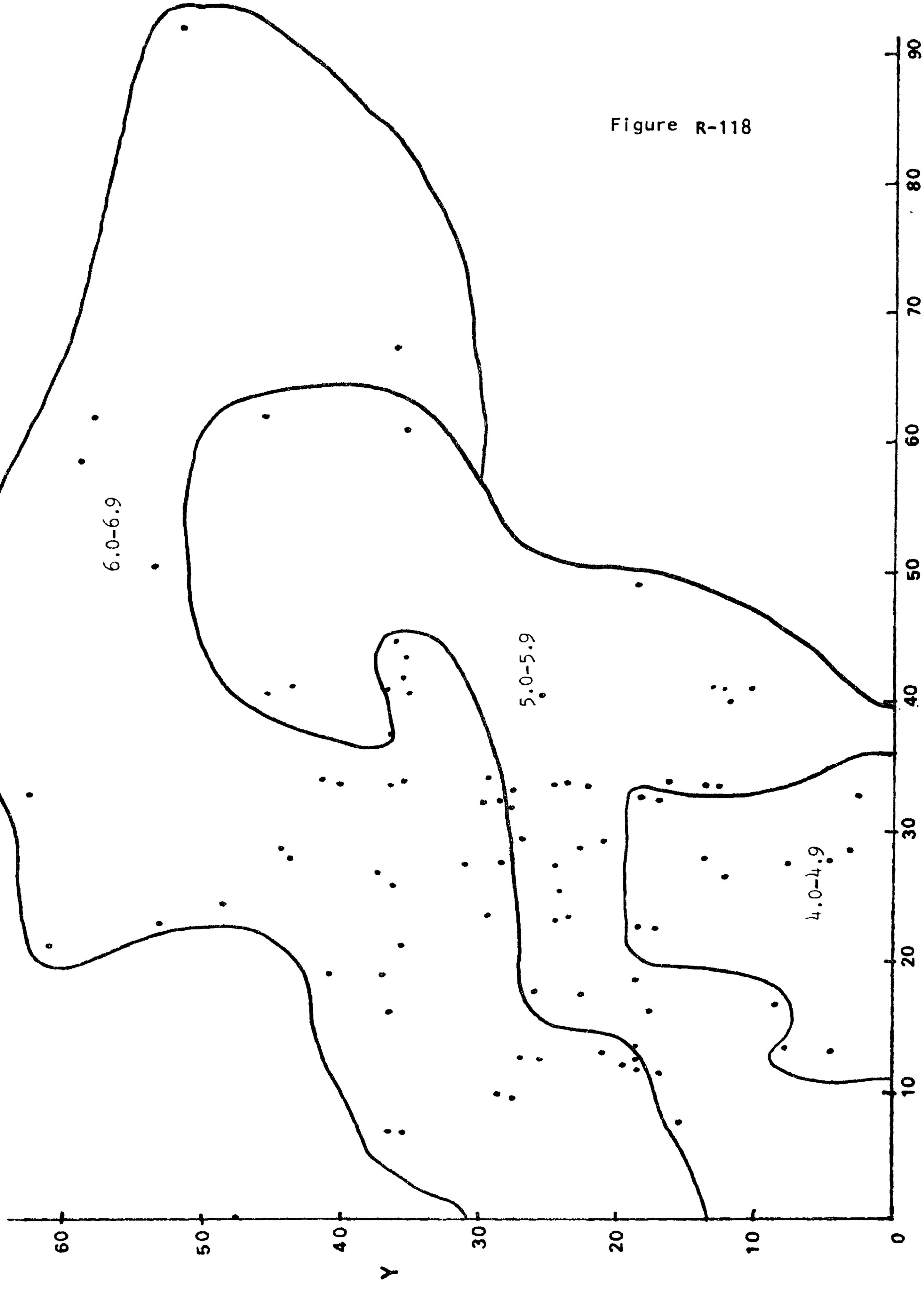


Figure R-118

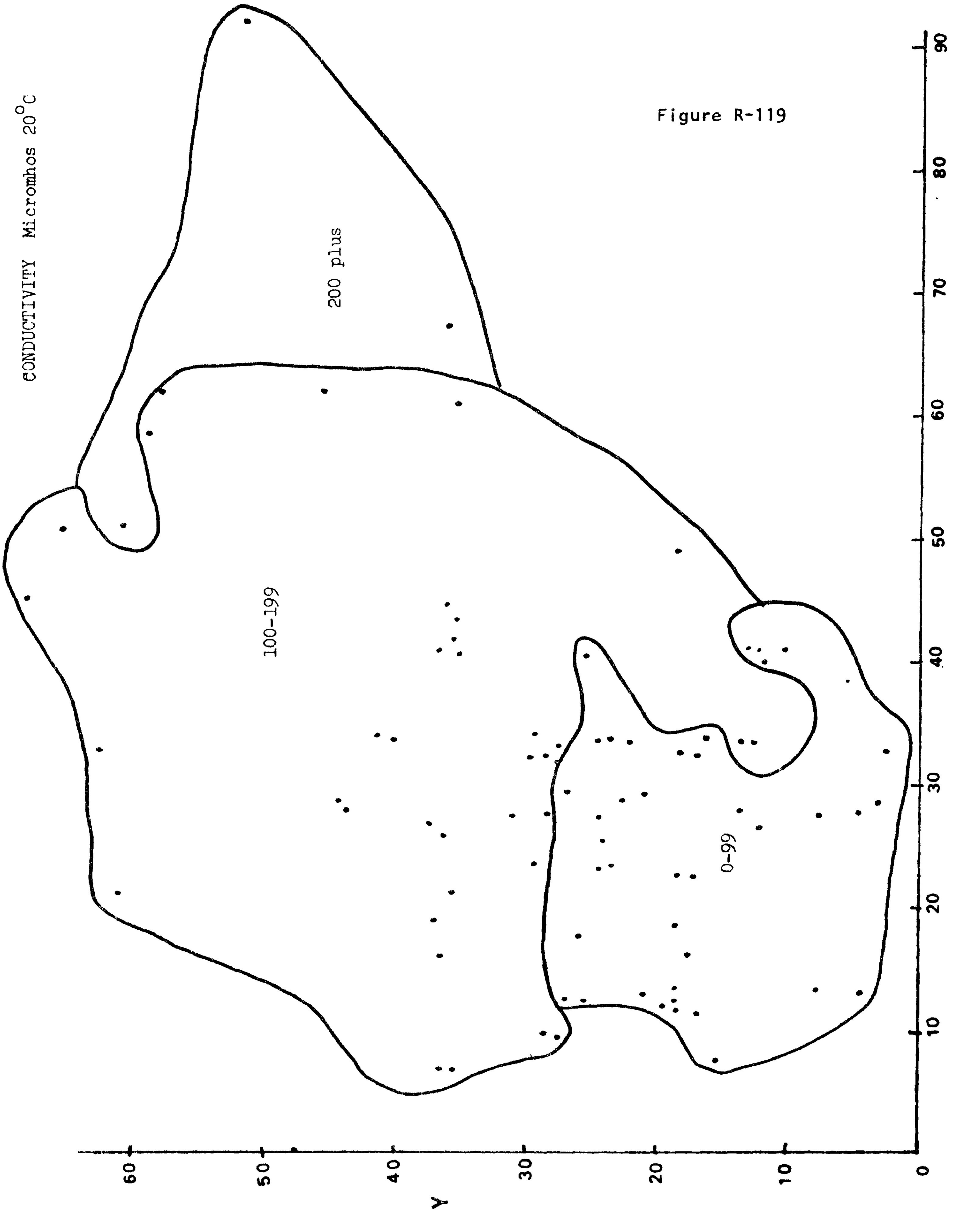

CONDUCTIVITY Micromhos 20°C
200 plus
100-199
0-99
X
Y
0
10
20
30
40
50
60
70
80
90

Figure R-119

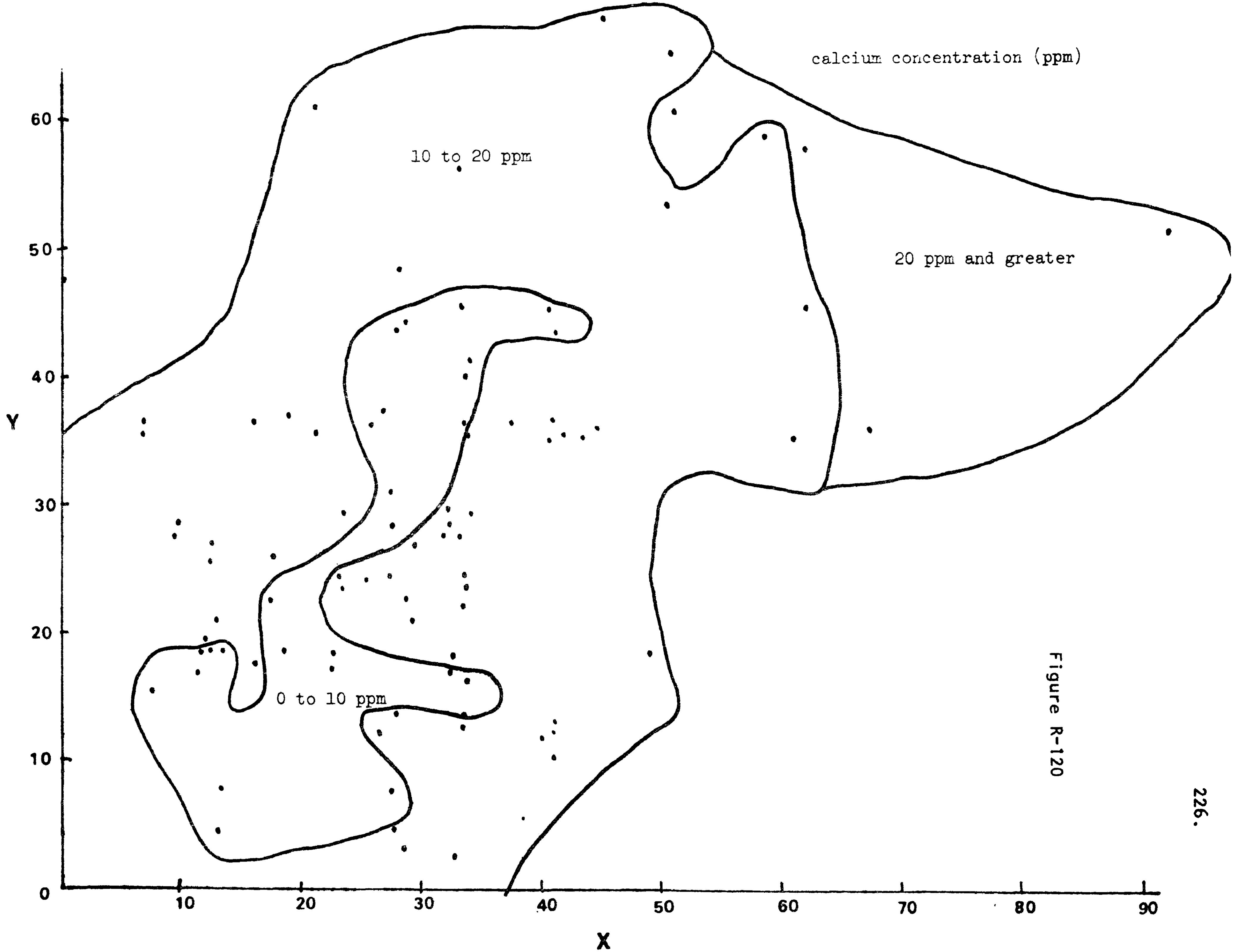

calcium concentration (ppm)
10 to 20 ppm
20 ppm and greater
0 to 10 ppm
Y
X
0
10
20
30
40
50
60
70
80
90

Figure R-120

grouped on the ordination as 0-20 cm of water above ground surface, 0-10 cm beneath ground surface, 10-20 cm beneath, and 20 cm and greater beneath ground surface. The "driest" siteswere in the lower left region of the ordination and the wettest sites in the upper right. Depth to water table did not follow a continuous gradient from dry to wet sites. Ten to 20 cm beneath ground surface category was divided roughly in half by the driest group. The driest group corresponded roughly to eastern muskeg and transition sites which were drier than northern or western sites. The wettest group contained fen and western transition sites.

(ii) Carbon-to-nitrogen ratio

Carbon-to-nitrogen ratios (see Table R-114) calculated for soil samples from each quadrat wereplotted on the ordination in Figure R-117. The C/N ratiodecreased along the gradient from muskeg to fen. Fen sites had more total nitrogen than muskeg sites.

(iii) Soil pH

Soil pH readings are plotted on the ordination and grouped into Jeglum *et al*'s (1974) trophic classes (see Table R-114) in Figure R-118. The trend along the scatter of quadratswas from oligotrophic sites (pH 4.0-4.9) to eutrophic (pH 6.0-6.9) sites, the trend seemed to follow the Y axis with a slight tendency toward positive slope. Oligotrophic siteswere concentrated in the eastern muskeg and transitions and eutrophic siteswere widely distributed through northern and western sites, as well as within the fen. The most acidic peat pH was 4.52 in quadrat A-5 (east muskeg). The highest peat pH was 7.25 in quadrat F-85 (western fen).

(iv) Conductance

Conductivity readings were grouped as 0-99 μmhos, 100-199 μmhos and 200 plus μmhos and plotted on the ordination in Figure R-119. The higher the conductance reading, the greater the dissolved mineral content of the water sample (see Methods II).

Conductivity increased through the ordination (see Figure R-119). Dissolved mineral status of water samples was least (0-99 μmhos) in eastern muskeg and transition zones, intermediate (100-199 μmhos) in northern, western and some fen sites and greatest (200 plus) in the wettest fen sites. The lowest conductivity measurement was 15 μmhos in the western muskeg quadrat E-63, the highest, 262 μmhos in F-89, west fen.

(v) Calcium

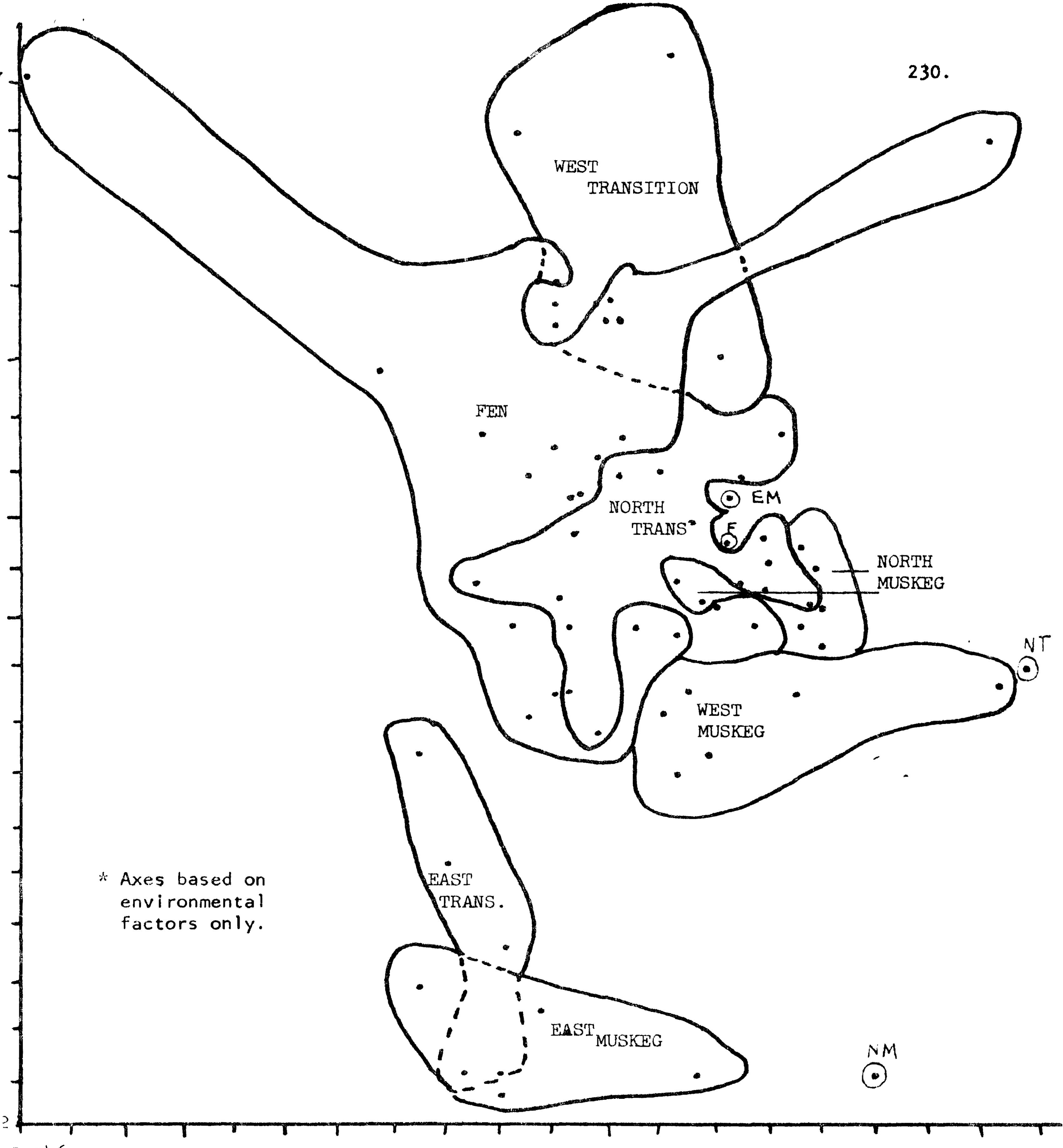
Figure R-120 depicts the calcium content of water samples, in parts per million, grouped by increments of 10 ppm. Calcium content for the majority of sites fell into the 10-20 ppm range. Sites with low calcium content (0-10 ppm) were concentrated in the eastern transition and muskeg sites, as well as in the western muskeg. Wet fen sites had the (20 plus ppm) most calcium present in water samples. Quadrats A-5 and A-8 (east muskeg) had the lowest calcium concentration, 3.3 ppm and quadrat F-84 (west transition) had the greatest concentration at 141 ppm.

Soil pH, water conductance and calcium content all increased along a vegetation gradient which ran from east muskeg and transition, through west muskeg, north muskeg, north and west transition culminating in the fen.

Depth to water table and carbon to nitrogen ratio both decreased along the same gradient.

b) Principal Components Ordination of Quadrats using Axes constructed from environmental data only

Examination of environmental factors plotted on a Bray and Curtis ordination, constructed from presence-absence floristic data only, revealed that there existed a gradient of environmental factors as well as in vegetation distribution. With Principal Components analysis it was possible to use environmental factors alone to construct ordination axes. Figure R-121 is an ordination of 74 quadrats from transects B-F located within axes constructed entirely of ten environmental measurements from each quadrat. Superimposed on the ordination were subjective classification groups of quadrats. Unlike than the continuous scatter of points which resulted from ordinations using floristic data exclusively, (see Results Vegetation section) some group formation was evident. Eastern transition and eastern muskeg sites are distinct from the rest of the sites sampled. Fen, north transition and north muskeg sites were the most similar, while west muskeg was distinct from western transition, although, both were similar to the fen.



* Axes based on environmental factors only.

AXIS 2*

N=north E=east W=west
M=muskeg T=transition F=fen

Figure R-121 Principal components analysis (Pearce 1969) ordination of quadrats 16 to 89. Quadrats are grouped by their subjective classification. Circled quadrat points are ordinated away from the bulk of quadrats in their subjective group.

Table R-122 helps to pinpoint the environmental factor, or factors, which most influenced the distribution of quadrats within the ordination. The factor which accounted for the greatest percentage of the total variance ~~is~~ conductivity, or the dissolved mineral status of the groundwater. Conductivity was also significantly positively correlated ($p \leq 0.001$) to ordination axis 1. Calcium content of groundwater was also significantly positively correlated to axis 1 together with the pH of water samples. These were all factors present in the groundwater.

Quadrats, when classified by physiogamy, follow axis 1 along groundwater characteristics. Eastern sites had the lowest values, they were most acidic with the least dissolved minerals and calcium, while western transition sites were less acidic with more dissolved minerals and calcium. The proportion of total variation within the data accounted for by axis 1 was 0.4416, almost half.

Environmental factors significantly correlated to axis two were the total % C, % H, and % N of soil samples. As quadrats were sorted along axis 2 the values for each of these factors increased Axis 2 accounted for less of the total variation (0.2152) than axis one. Results of correlations of environmental factors to axis two were not as clear cut as correlations to axis 1. Axis two did not provide as much insight into underlying environmental gradients as did axis 1.

Table R-122 Correlation of ten environmental factors and component axes 1, 2 and 3

Transects B to F, 74 quadrats

	Axes 1	2	3	% of total variance
proportion of total variance accounted for	0.442	0.215	0.097	
Factor \ correlation of factor with axis				
von Post humification	-0.305	0.044	0.111	9.72%
soil pH	0.299	0.322	-0.473*	9.71%
Loss on ignition	-0.306	0.204	0.406*	10.09%
Total % Carbon	-0.322	0.437*	0.073	9.76%
Total % nitrogen	0.048	0.554*	0.004	9.72%
Total % hydrogen	-0.293	0.474*	0.089	9.72%
Depth to water table	-0.293	0.065	-0.522*	9.73%
Water pH	0.376*	0.268	-0.319	9.71%
Conductance	0.396*	0.212	0.395*	12.12%
Calcium	0.385*	0.103	0.238	9.73%

* significant at $p \leq 0.001$

c) Principal components ordination of species using axes constructed from floristic and environmental data

Figure R-123 is an ordination of 38 species which achieved a frequency of greater than 5% from 74 quadrats along transects B-F. Ordination axes were constructed from floristic presence-absence data and ten environmental measurements from each quadrat (soil pH, water pH, calcium, conductance, loss on ignition, von Post humification, total C, H, N and depth to water table). Species were gathered into groups which often occured together in the study area.

Results of previous ordinations (Tables R-56 and R-122) indicated that environmental factors accounted for the greatest proportion of variation along the axes and that floristic factors accounted for much less. Species in Figure R-123 were sorted into groups which appeared to be related to environmental parameters, particularly soil and water pH, conductance and calcium content of water.

Picea mariana, *Ledum groenlandicum*, *Pleurozium schreberi* and Smilacina *trifolia* were species common to drier muskeg sites, particularly those on the east side. East side muskeg sites were characterized by low soil pH, water pH, low conductivity and low calcium concentrations.

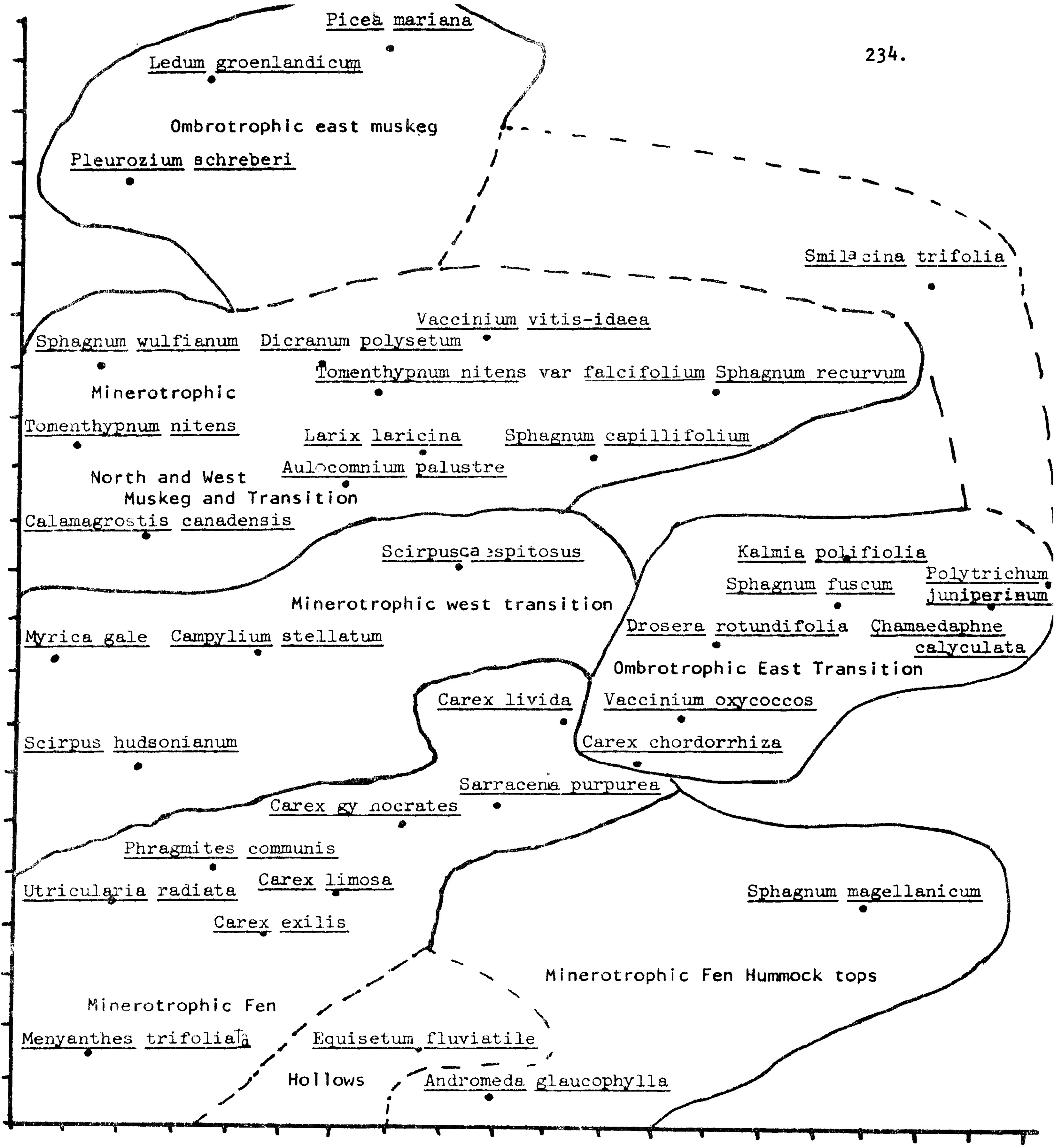


Figure R-123 Principal components analysis of 38 species grouped by location and environmental condition of the sites where they are most frequently encountered. Axes based upon both floristic and environmental data.

Transition species, *Sphagnum fuscum*, *Polytrichum juniperinum*, *Chamaedaphne calyculata*, *Vaccinium oxycoccos*, *Kalmia polifolia*, and *Carex chordorrhiza* were commonly found on hummocks, especially hummock tops, in the dry eastern transition. Soil and water pH, conductance and calcium concentration readings were low to intermediate in these sites. *Sphagnum magellanicum* and *Andromeda glaucophylla* were transition species which occupied wetter sites and had a wider distribution throughout the study area, occurring in all transition zones. *Sphagnum magellanicum* often formed large loose hummocks well out into the fen, as well as, in the wet hollows of the transition zones. *Andromeda glaucophylla* occupied the wettest habitats of all the Ericaceous shrubs present in the study area. Wetter sites had higher pH's (5-59 mesotrophic and 6-6.9 eutrophic) greater conductance and more calcium than did eastern muskeg or hummock tops.

Equisetum fluviatile *Menyanthes trifolia* *Carex exilis* and *Utricularia radiata* were species characteristic of fen sites, although, *Equisetum fluviatile* occurred well into the hollows of the transition zones and muskeg. *Phragmites communis* grew in patches in the wettest parts of the fen. Fen sites were characterized by eutrophic pH's, high conductance values (200 plus) and plentiful calcium ions (20 ppm plus).

Within the eastern portion of the fen were hummocks of *Sphagnum magellanicum* which were often topped with the insectivorous *Sarracenia purpurea*, and tussocks of *Carex livida*. To the west of the fen's centre were tussocks of *Scirpus* caespitosus and *Scirpus hudsonianum*. In the hollows between these tussocks *Campylium stellatum* was very common. All these sites were eutrophic, with high conductivities and calcium concentrations.

Species located in the upper and left central portion of the ordination occurred in drier sites that were eutrophic. These were the northern and western transition zones.

Larix laricina was very common in the northern transition zone. It occurred as very small trees in a matrix of large *Sphagnum magellanicum* hummocks. Aulacomnium *palustre* often grew on these hummocks. The *Sphagnum* species *S. capillifolium* and *S. recurvum* were frequently found in wetter sites throughout all the transition sites in the study area.

Myrica gale, *Calamagrostis canadensis*, *Tomenthypnum nitens* and *Sphagnum wulfianum* had a limited distribution that was restricted to a narrow belt of transition on the west side of the fen. This belt was very wet, lacked large dry topped *Sphagnum fuscum* hummocks, and was dominated by the shrub *Myrica gale*. This transition had a high pH (eutrophic) conductivity and calcium concentration.

Deeper into the west side transition zone, almost within the muskeg, small hummocks of *Dicranum polysetum* and patches of *Tomenthypnum nitens var falcifolium* were present within a tangle of *Ledum groenlandicum*, *Chamaedaphne calyculata* and *Kalmia polifolia*. *Vaccinium vitis-idaea* was often present on the hummock tops. This site was less eutrophic, often mesotrophic, conductivity was less (100-200 mhos) and calcium concentration was lower (10-20 ppm). West side muskeg had *Ledum groenlandicum* more frequently than on the east side, pH values were higher and it was often invaded by species such as *Calamagrostis canadensis* and *Myrica gale*. Bryophytes present were often species not common to east side muskeg, and included a diverse and interesting variety of Sphaanum species.

The ordination of species based upon environmental and floristic data resulted in an arrangement of species which was predominantly determined by their location within the study area. These locations were often defined by levels of soil and water pH, conductivity and calcium concentration. East side sites tended towards oligotrophy, were drier, and had fewer dissolved minerals than wet, mesotrophic and eutrophic west side sites.

P.C.A. ordinations of quadrats demonstrated that it was possible to separate eastern sites from western sites on the basis of environmental factors alone (Figure R-121). Ordinations based on floristic data only did not separate eastern sites from other sites, but; instead demonstrated a continuum of sites whose lower extremes were eastern and upper extremes were western.

Discussion

Introduction

The results of observations and analyses of vegetation, soils, groundwater and climate in William Bog indicate that within the study area there exists a complex of vegetation types that are closely related to one another floristically, and apparently associated with varying soil and groundwater conditions. Discussion of these results is directed toward elucidating the nature of vegetation structure, community development in relation to soils, groundwater and microclimate, and community dynamics, successions and cycles present in the muskeg-fen complex in which the study was undertaken. This discussion will begin with comments on the appropriateness and usefulness of the methodology, primarily those methods used in analysis of vegetation, soils and groundwater data.

Comments on methodology

Methods of sampling vegetation, soils, water and climates in William Bog are standard techniques employed in the sciences of plant ecology and climatology. Sampling methods proved satisfactory in most cases and will only be commented upon in this section when discussion of sampling methodology is necessary or appropriate. Method of Analysis of ecological data is a subject which can be controversial and has been discussed at great length in the literature (see Greig-Smith, 1964; Kershaw, 1973 etc.). Analyses undertaken in this study will be justified and commented upon in this section before the results of these analyses are discussed.

Initially, the vegetation of the study area was classified subjectively using ground surveys and aerial photography. This approach to analysis of vegetation structure in wetlands has been used successfully by Ritchie (1962), Radforth (1958), and Jeglum and Boissonneau (1977). This type of classification successfully facilitated reconnaissance mapping of the study area, which was necessary before decisions about sampling techniques could be finalized.

Once quantitative floristic data are collected, objective analysis of vegetation structure can be approached in two ways, depending upon the heterogeneity of the data. Either data can be objectively classified initially, or ordinated initially.

Greig-Smith (1964) concludes that data should be ordinated initially, regardless of its heterogeneity. Thus, relationships between samples can be assessed and classification can proceed, if necessary. However, Lambert and Dale (1964) recommend classification initially (Williams and Lambert, 1959, Normal Association Analysis, specifically) because heterogeneity is inherent to all vegetation and classification of samples is necessary to elucidate the structure of the data. Greig-Smith, Austin and Whitmore (1967) suggest classification initially for data with a lot of variation between samples and ordination initially for data with low levels of variation. Goodall (1963) and Whittaker (1967, 1973) recommend ordination initially when vegetation gradients are to be examined.

Analysis of floristic data from quadrats 1-100 was approached in such a manner that gradients could be identified and related to classifications, individual species behaviour, and to measurements of water and soil characteristics. Vegetational heterogeneity in the study area was low, data was ordinated initially and then objectively classified.

Ordinations have been used to locate quadrats between axes derived from Coefficients of Similarity (C.S.) by Bray and Curtis (1957). Mathematically sophisticated methods of ordination, based upon elaborate multivariate techniques, have been developed recently. Principal components analysis (Pearce, 1969) has been described as 'the most successful ordination technique currently employed' by Gittins (1969). However, Beals (1973) believes that P.C.A. makes many unreal assumptions about ecological data and concludes that Bray and Curtis ordination is not just a 'crude approximation to a genuine mathematical system' (Lambert and Dale, 1964), but a model preferable to P.C.A. because it defined changes in vegetation from point to point, rather than within a multidimensional hyperspace. (See Methods-III Analysis of vegetation data.) Beals considers the multidimensional hyperspace ecologically unreal, but point to point analysis a more realistic model of vegetation behaviour.

Comparisons of Bray and Curtis ordination models with P.C.A. models (Orloci, 1966; Austin and Orloci, 1966; Gauch et al., 1977) indicate that, although P.C.A. is more elaborate, the resultant ecological information obtained from the ordinations is similar, and often more clearly defined, in Bray and Curtis ordinations.

Consequently, vegetation data was ordinated initially using the methods of Bray and Curtis. Quadrats were then classified by Normal association analysis (Williams and Lambert, 1959). This process yielded good results and produced an ecologically realistic model of the vegetation relationships present within the study area (see Figure R-30) which demonstrated the presence of a vegetation gradient in which loosely formed species groups could be identified. The elimination of certain quadrats from the Normal Association Analysis (see Table R-49) was justified because these quadrats were classified at low chi-square levels on the basis of species recorded in only 10% of the quadrats (minimum acceptable frequency for species in this analysis). The grouping of quadrats whichresulted from this classification was not reflected in their locations on the Bray and Curtis ordination. Ward (1970) subjectively reclassified such quadrats, while Goodall (1969) removed them from his analysis. Quadrats removed from Normal analysis in this study are circled on Figure D-1.

A P.C.A. ordination of data from transects B-F was similar to the Bray and Curtis ordination in the manner that it locates quadrats between component axes (see Figure R-53). However, when the classification scheme resulting from normal association analysis was applied to the P.C.A. ordination, many quadrats appear to have been misclassified, and the ecological gradient of species groups was not so evident.

Consequently, the Bray and Curtis ordination was concluded to be a better model of the study area when P.C.A. ordination axes were constructed with floristic data only. P.C.A. ordination did, however, produce ecologically realistic ordinations when axes were constructed with environmental measurements of soil and water characteristics (see Figure R-121) (see Discussion III Vegetation-Environment relationships). P.C.A. ordination axes had no end points, ordinations within the hyperspace were often distorted when quadrats were located between only two axes (Whittaker, 1973). When Bray and Curtis ordinations were compared to P.C.A. ordinations using simulated vegetation gradients, P.C.A. consistently produced curvilinear distortions of gradients which were linear on Bray and Curtis ordinations. (See Austin and Noy-Meir, 1972.) Curvilinear distortion in P.C.A. ordinations of William Bog data was evident when they were compared to Bray and Curtis ordinations. In P.C.A. ordination of data, using axes composed of floristic data alone, the relationship between Normal groups had been twisted along a curving path. In Bray and Curtis ordination the relationship was linear.

Because the Bray and Curtis ordination represented gradients within the study area linearly, it was utilized as the arrangement of quadrats upon which details of floristic cover and environmental parameters were plotted.

Analyses of floristic and environmental data were successful at objectively organizing data into groups and gradients which substantiated subjective observations of vegetation structure within the study area. The nature of existing plant communities and their interrelationships with each other and the environment will be discussed in the following section of this paper.

II The Nature of Vegetation in William Bog

a) The total flora

This study has yielded a collection of vasculars, mosses, and hepatics which was, while not a complete flora of the whole William Bog, a thorough collection of the area in which transects and climatic measurements were undertaken. The vascular flora (71 species) was slightly richer than the bryophyte flora (37 species), and of these, the Cyperaceae, particularly *Carex spp.* were dominant, although the Ericaceae and Salicaceae were well represented. Vascular species listed in Table R-1 correspond very well to Baldwin's (1958) list of wetland species common in the clay belt of northern Ontario and Sjors (1963) list of wetland species present near the Attawapiskat River near Hudson's Bay.

Four species of insectivorous plants were collected, *Drosera rotundifolia*, *D. angelica*, *Sarracenia purpurea* and *Utricularia radiata*. This was an average number of such species for wetlands in this area. Bannister (1976) noted that insectivorous plants usually exist in boggy habitats which were lacking available nitrogen. His list of insectivorous plants common to temperate wetlands corresponds well to insectivorous collections from William Bog. *Myrica gale* was present in the study area. It has root nodules capable of fixing nitrogen (Bannister, 1976). The moss *Splachnum ampullaceum* was also present, it grew specifically on moose pellets which are a rich source of nitrogen. Thus, in William Bog, the nature of the peat, anaerobic conditions, and pH combine to produce a nitrogen poor environment in which several species exist that can utilize alternate nitrogen sources.

b) Vegetation Zones Present

A total of twelve different vegetation zones were recognized in the study area (see Figure R-4). These zones were distinct, but tend to overlap (indicated by dotted lines) and borders between zones were located arbitrarily on the map. A floristic description of each zone can be found in Results - I-b.

Sampling of vegetation and environmental data along transects within the study area included eleven of the twelve zones (except zone 2), but results were generalized into nine major physiognomic groups for analyses of soils and groundwater data. It was found that this generalization did not hinder the proposed interpretation of the nature of vegetation communities present within the muskeg-fen complex examined.

LEAF 245 OMITTED IN PAGE NUMBERING.

Analyses of point quadrat data and ordinations indicate that frequently occurring species are usually continuously distributed throughout the study area when considered on a presence-absence basis only. When cover of these species was noted it was usually maximum in the vegetation community that they had been proposed to characterize.

Picea mariana had high cover in three vegetation zones (1, 11 and 12) producing a continuous overstorey which surrounds the study area on the east, north, and west sides. This species alone was used to subjectively classify muskeg sites in initial surveys when over 2 metres in height and with cover greater than a Braun-Blanquet value of 3. Figures R-6 and R-47 illustrate that *Picea mariana* tends to be continuously distributed in the drier sites which are furthest from the fen. However, when the composition of the under-storey in these sites was taken into consideration it suggests that muskeg sites could be subdivided into three zones, east, north and west of the fen each of which was the beginning of a vegetation gradient which runs from muskeg to fen centre.

The eastern most zone (zone 1, *Picea mariana* muskeg forest) appeared to be similar to bog forest vegetation already documented in the literature. ("Moss-muskeg", Ritchie, 1960a, 1960b; Heinselman, 1970 - "black spruce-feather moss forest" and "Sphagnum-black spruce-leather leaf bog forest", see also Jeglum (1972) "muskeg" and Jeglum _et_ _al_., (1974) "Shrub-rich treed bog"). This bog type vegetation graded into a shrubby zone (zone 3) which tends to be characterized by well developed *Sphagnum fuscum* hummocks and a thick layer of ericaceous shrubs dominated by *Chamaedaphne calyculata*. *Picea mariana* extends into this zone, but cover was low and distribution was restricted to hummock tops, the rapid growth of which has resulted in layered (McEwen, 1966) growth habits in *P. mariana*. *P. mariana*'s distribution in this zone may in part also be limited by an alleopathic, water soluble substance present in the roots of *Kalmia polifolia*. Peterson (1965) reported such a substance in the roots of *Kalmia angustifolia*. This shrubby open zone may be maintained through the successful competition of *Sphagnum fuscum* and *Kalmia polifolia* with *Picea mariana*. Although labelled transitional, this was likely a permanent zone similar to Segadas-Vianna's (1955) "*Chamaedaphne* community", Moss's (1953) "open bog", Jeglum et al.'s (1974) "low shrub bog" and Gauthier and Grandtner's (1975) "Sphagno-Chamaedaphnetum".

Vegetation along this eastern gradient exhibited an increase in cover of fen species as it developed into a wet zone (zone 4) where *Sphagnum magellanicum* replaces *S. fuscum* as the dominant hummock builder. This zone appeared to be transitional between fen type vegetation (Sjors, 1963) and low shrub bog. Species composition was mixed, fen-like in the hollows and bog-like on the summits of the *Sphagnum magellanicum* hummocks. The *Carex spp.* flora was not well developed which could suggest either paludification of a drier low shrub bog (see Moore and Belamy, 1974, p. 62) or invasion of fen vegetation by *Sphagnum magellanicum* whose rapid growth overtook *Carex spp.* and resulted in a drier habitat unsuitable for their colonization. *Equisetum fluviatile* was common in this and all the fen sites (zones 5, 6, 7 and 8). When plotted on the Bray and Curtis ordination (Figure R-42) cover of this species indicates that it had a broad ecological amplitude and doesn't achieve cover values greater than one in any but the very wettest sites.

Zone 5 was on the eastern edge of the fen. This was the hummocky region of the fen in which many *Carex* species thrive singly or in tussocky complexes interconnected by very wet hollows. In this zone insectivorous species were most commonly encountered, especially on the wet *Sphagnum magellanicum* hummocks (*Sarracenia purpurea*) and in the open waters of the hollows (*Utricularia radiata*) (see Figure R-40). This region of the fen was not quaking and appears to be in dynamic equilibrium with the wet transitions to the east (zone 4) and north (zone 10). If *Sphagnum magellanicum* hummock development proceeded rapidly in this graminoid fen (Jeglum et al., 1974) it would eventually fit the characteristics of a graminoid bog (Jeglum et al., 1974). Note that *Carex limosa*, (Figure R-43) a species which characterizes the graminoid bog, was broadly distributed in the study area. Its numerous optimum habitats on the ordination likely cor-corresponed to samples taken in hollows present in many of the subjectively determined vegetation zones. This indicated that the nature of vegetation in zones 4 and 5 was a transition between true bog and fen types, but fen characteristics dominate zone 5.

Zone 6 was the wettest part of the fen, a quaking *Carex spp.* mat. Cover of *Equisetum fluviatile* was greatest in this site. This zone was similar to Heikurainen's (1960) "Scorpidium Letto", Sjors (1963) "rich fen" and of Jeglum et al.'s (1974) "graminoid fen". It can be considered a true fen. The brown mosses were well represented, these species demand a high level of nutrients in order to thrive (Heikurainen, 1960). Within zone 6 there were patches of *Phragmites communis* (zone 7) which characterize deep or shallow marshes (Jeglum et al., 1974). However, peat was deeper than 30 cm in depth in these sites indicating that these patches of *Phragmites communis* could be relics of an earlier, wetter community. Gorham (1957) noted that *Phragmites* is deep rooted and can survive in a site centuries after surface conditions have become inappropriate. Zone 8 consisted of patches of *Eriophorum spissum* which likely result from rhizomatous growth habit and development over many years. This species appeared to actively outcompete *Carex spp.* in these sites, which are really vegetation patches rather than true communities. Zones 6, 7, and 8 were likely all graminoid fen sites and will be considered as such for the duration of the discussion section.

A gradient from treed bog to graminoid fen existed through the study area from the east to fen centre. Along this gradient species composition varies continuously and species with high frequencies were found in a variety of sites. Cover of such species was greatest in the vegetation zone where environmental conditions were optimal for development of that species. East of the fen, vegetation structure indicates that sites could be considered "poor" (Heinselman, 1970) or ombrotrophic (Sjors, 1963). Examination of environmental data confirmed this theory. Gradients of soil pH (Graphs R-104 and R-105) illustrated a gradient from oligotrophy to mesotrophy running from east to fen centre. Conductivity and calcium concentration increased along this gradient (Tables R-97 and R-98) indicating increased mineral concentration in the fen. These results agree with the findings of many authors (Gorham and Pearsall, 1956; Sjors, 1961, 1963; Heinselman, 1963, 1970; Jeglum 1973 ; Vitt and Slack, 1975; Vitt et al., 1975; Tilton, 1977; Schwintzer, 1978; Johnson, 1977a, 1977b; Wildi, 1978 etc.) all of whom acknowledge the relationship between soil and groundwater conditions and wetland vegetation type.

However, it was not possible to document an environmental gradient from ombrotrophic to minerotrophic sites using water and soils data from transects north and west of the fen (see Graphs R-104 and R-105). Physiognomically these sites were similar to those on the east side, but environmentally and floristically the resemblance between muskeg sites seems to end with the presence of *Picea mariana*.

Zone 11 was a wet mixed *Picea mariana*-*Larix laricina* stand north of the fen whose understorey consisted largely of broad-leafed *Carex* species. This was a rich site which was floristically very similar to Ritchie's eutrophic "larch fens" (Ritchie, 1960a, 1960b), Sjors (1963) "forested rich fen" Heinselman's (1970) "rich swamp" and of Jeglum et al. (1974) "*Larix laricina*-graminoid rich treed fen". Environmentally, this site fits definitions of eutrophic (water pH (June) 6.65) and minerotrophic (calcium - 14.96 ppm, conductance (June) 150.12 umhos) according to Sjors (1963) and Jeglum et al., (1974). The significance of environmental measures in all sites will be fully discussed in the next section of the Discussion.

Zone 11 graded into an open type of vegetation towards the fen (zone 10) which was similar to Jeglum et al. (1974) "*Larix laricina*-*Sphagnum* rich-treed fen". This appeared to be a westward extension of the zone of large *Sphagnum magellanicum* hummocks included in zones 4 and 5 within which an open stand of *Larix laricina* was developed. This could be an example of a fen site which was gradually being invaded by *Sphagnum spp.* hummock development. However, this was a relatively rich site (eutrophic pH), richer than the graminoid fen (zone 5) immediately to the south. The peat surface of both zones 10 and 11 was laced with many drainage channels and deep holes, similar to those described by Jeglum et al. (1974) in sites classified as swamps. These channels indicated subsurface flow of water through zones 10 and 11. Vegetation in relation to drainage will be examined in the community development portion of the discussion.

Zones 11 and 12 mix in the extreme northwest region of the study area. Gradually, the graminoid rich treed fen dominated by broad leaved *Carex spp.* Gave way to a mixture of *Picea mariana*, *Larix laricina*, and *Thuja occidentalis* forest whose understorey was dominated by *Calamagrostis canadensis*. *C. canadensis* had a high nutrient demand (Dansereau, 1959), indicating that this was likely a rich site. Measures of pH, calcium concentration and conductance confirm this theory. This was the wettest of the forested sites in the study area, but it was not as rich as the northern treed fen site. This region matches Jeglum et al. (1974) "graminoid rich treed fen" description, but trees were not so widely spaced. Both zones 11 and 12 also fit Jeglum et al. (1974) general description of a "conifer swamp". Likely both these forested sites could be considered a single coniferous swamp surrounding the fen to the north and west.

Zone 9 lies in the midregions of a vegetation gradient running from the west to fen centre. It was a very narrow shrubby band dominated by *Myrica gale* and at least nine species of *Salix*. Sphagna were virtually absent and tussocky *Scirpus* spp. and *Carex spp.* were common.

The peat surface was criss-crossed by drainage channels and animal trails and was frequently quaking. It was a rich site, richer than the conifer swamp to its west. This wet zone can be classified as a "shrub carr" (White, 1965) or a "thicket swamp" (Jeglum et al., 1974) in its westernmost regions and a "low shrub fen" (Jeglum et al., 1974) as shrubs become smaller and less vigorous towards the fen to the east. Zone 9 terminated in the *Phragmites* and *Eriophorum* patches within the graminoid fen. This region of the fen was the richest of all sites sampled in the study area. It was always quaking and peats were decomposed to the point where they will

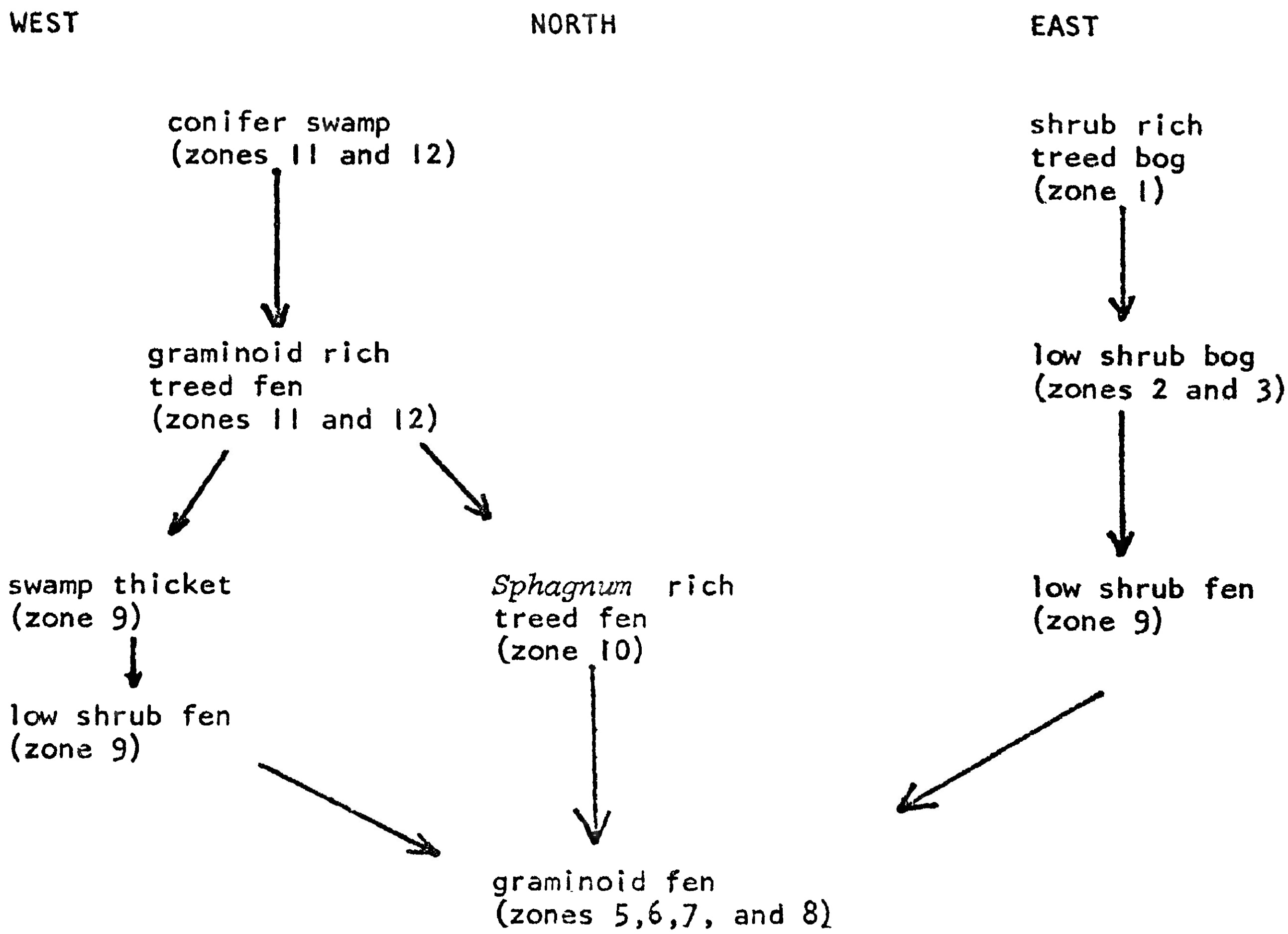


Figure D-2 Summary of floristic relationships, vegetation gradients, vegetation communities, and site types present in sites west, north, and east of a central graminoid fen. William Bog, Thunder Bay, Ontario.

not support the weight of an adult female. This terminates a vegetation gradient from swamp to fen. pH conditions do not follow a smooth gradient as they do on the eastern side of the fen. Rather, they remain eutrophic along the entire gradient. This demonstrates that conditions along the western gradient (and the northern gradient) were not the same as conditions along the gradient from ombrotrophic to minerotrophic sites east of the fen. In northern and western sites minerotrophy predominates. (Figure D-2 outlines vegetation communities and gradients present in the study area.) Reasons for this, and proposed development of vegetation in relation to environmental factors and vegetation's effect upon the environment will be examined in the following section.

c) Community development

The vegetation structure within the study area was the result of many interactions between topography, drainage of ground and surface waters, local climates and microclimates as proposed in Figure D-3.

In the beginning community development was controlled by local topography. William Bog developed in a shallow basin once occupied by glacial Lake Minong. This provided an appropriate environment for invasion of wetland species and stratigraphy indicated that peat deposition had been continuous since the basin was exposed from beneath the waters of Lake Minong 9000 years ago (Farrand, 1960). The climate of the area provided sufficient rainfall for wetland development (Zoltai *et al.*, 1974) and falls into a region of humid boreal bogs, fens, and swamps. As the peat body developed it modified

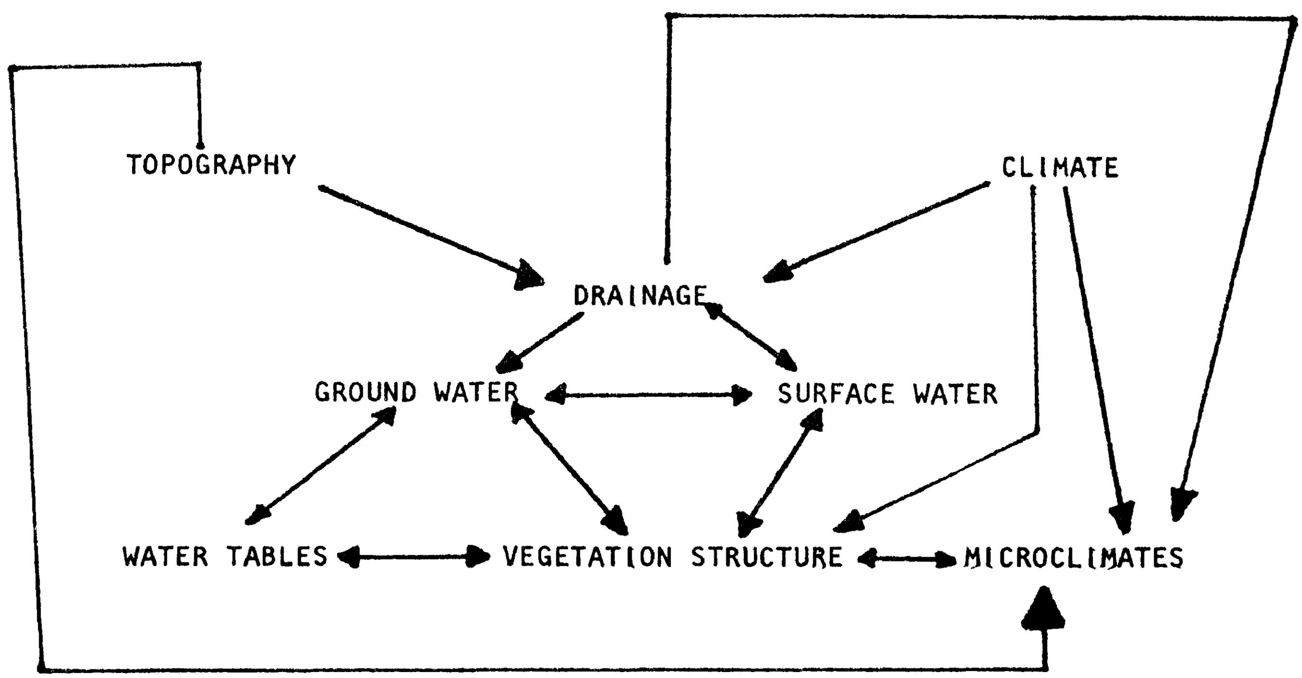


Figure D-3 Environmental factors and how they relate to vegetation structure in William Bog, Thunder Bay, Ontario.

the local climate, as well as being affected by local climatic variations which might be due to topography. William Bogwas subject to greater temperature extremes than nearby Thunder Bay Airport (3 km SW). Thiswas likely the result of cold air drainage into the confining basin, a fact recognized by Geiger (1965), in combination with the radiating and conducting capacity of the peat body. Peat provides a large evaporating surface, this evaporation results in rapid surface cooling, consequently poor conduction of heat from the surface to the peat body below (Transeau, 1905; Cox, 1910; Rigg, 1947; Longley and Louis Byrie, 1967). Williams (1968) noted similar variation between air temperatures in Mer Bleue bog in Quebec and sandy ridges nearby. Thus, the peatland produces and continues to develop on a cool peat body. During the growing season the temperature of the peat can vary from 20.3°C on the surface to -4.0°C 50 cm below the surface (June 23, 1978, zone 3) and pockets of frozen peat were detected in zone 1 at 30 cm and 50 cm below surface on July 17, 1978. Throughout the growing season peat temperatures remained cool, only surface temperatures and -3 cm temperatures warmed up. This was most evident in zone 3 where vegetational cover was low enough to allow some penetration of radiation through the peat surface. In wetter sites (zone 6, zone 9 and zone 12) groundwater tends to thaw peat earlier and reduce variation in temperature with depth, confirming Heikurainen's (1954) observation that peat temperature is inversely related to the depth to water table. As winter approaches peat temperatures tend toward uniformity with air temperatures in all sites. There was no evidence for permafrost in William Bog. The Thunder Bay region is well below the southern limit of the discontinuous permafrost zone (Brown, 1967) and no permafrost surface features such as peat plateaus or palsas were observed. Localized frost pockets, however, can persist well into the summer, especially in drier sites with heavy vegetation cover. Therefore, the peat body whose poor heat holding, and excellent radiating capacities will produce an environment with microclimatic extremes which ultimately can affect the nature of the surface vegetation. Species that exist in peatland habitats must be able to tolerate extremes in temperature during the growing season that range from several degrees of frost to over 30°C. This partly accounts for the xeromorphic nature of common vegetation, specifically the ericaceous shrubs in ombrotrophic transition zones (zone 2 and 3), where the highest peat surface temperatures of all sites were noted. Ground level temperature maxima and minima in this site (zone 3) were always lower and higher than ambient air temperatures in the same site throughout the growing season. This reflects both the conducting and radiating nature of the peat body. As ambient air temperatures dropped later in the season the peat surface, warmed only to a depth of 3 cm, radiates and remained warmer than the air for a short time before snowfall. Vegetation cover in zone 1 blocks incoming solar radiation and results in less extreme surface temperature maxima.

However, surface temperature minima were always cooler than ambient air temperature minima in the shrub rich treed bog during the growing season. As winter approached surface temperatures were warmed by radiation of heat from the peat body. The radiating qualities of the peat body kept the surface of the fen warmer than the ambient air temperature from July to October. This site (zone 6) did not exhibit the greatest temperature extremes at ground level, as seen in drier sites, because its surface was always flooded. Water has high specific heat and a greater heat carrying capacity than peat, whose specific heat is very low.

Within the developing peat body vegetation structure was largely controlled by the nature of its water supply. Where mineral rich groundwaters flow vegetation was fen-like in composition. Both Gorham (1957) and Sparling (1966) noted that water pH increased with the flow rate of groundwater. Flow rates were not measured in this study, but when pH was plotted on an outline map of vegetation communities (Figure D-4) the flow of groundwaters appeared to be from the north, through a coniferous swamp, into the fen. Communities along the path of groundwater flow vary from coniferous swamp forest to graminoid fen and share similar peat and groundwater chemical conditions that classify them as minerotrophic plant communities. Sjors (1950) preferred to keep his classification of wetland communities at a relatively general level because vegetation zonation is gradual and a variety of types and combinations can occur over a very small area.

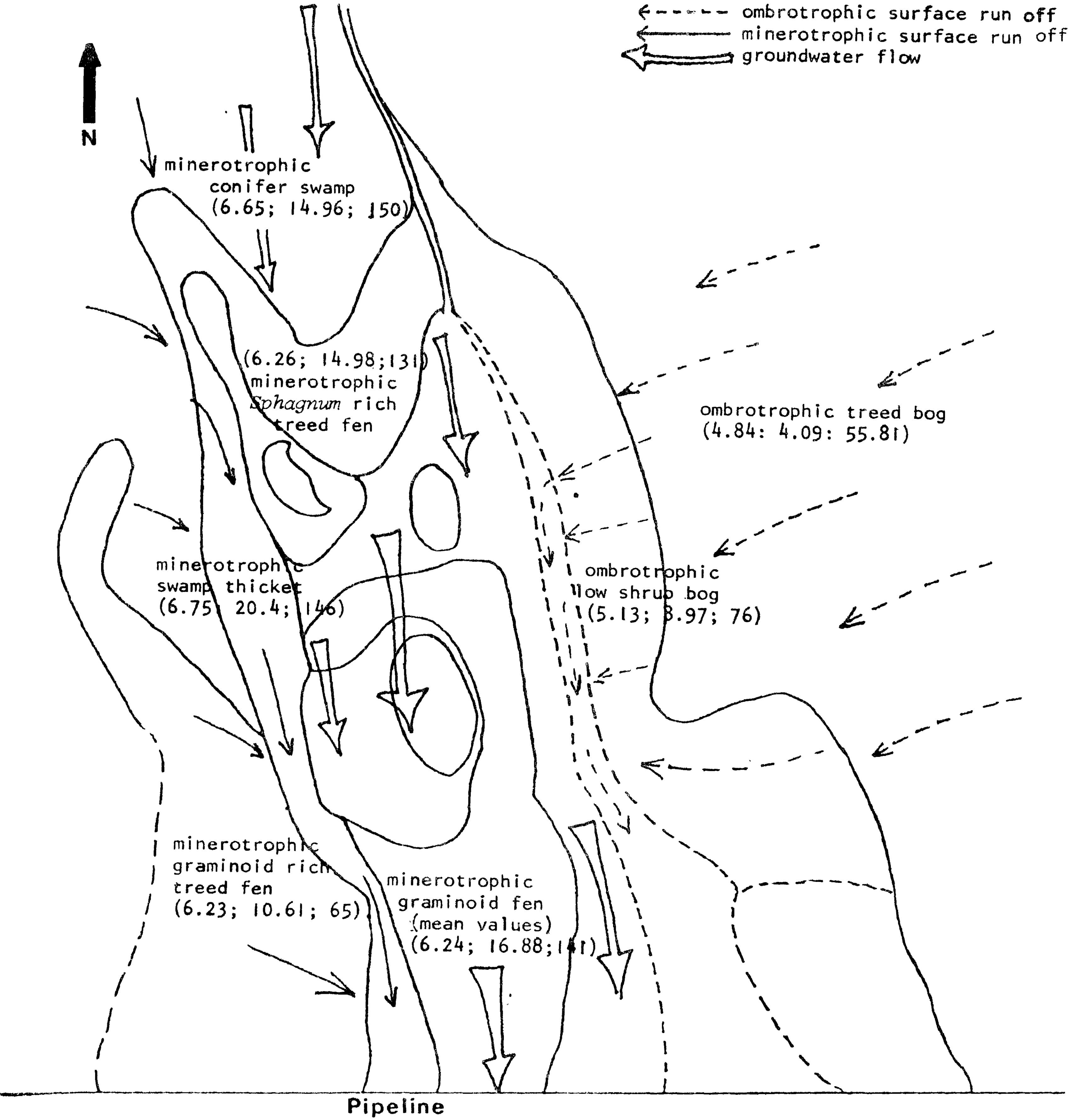


Figure D-4 Ground and surface water flow and site conditions in the central study area of William Bog.

values in brackets are (a; b; c)
a= June water pH
b= calcium (ppm)
c= conductivity (micromhos) June

Thus, in the study area minerotrophy was concentrated in the conifer swamps, treed fens, and graminoid fens that have developed in the path of groundwater flow, while ombrotrophic communities have developed adjacent to the groundwater drainages forming treed and low shrub bogs on poorer sites with lower pH and fewer minerals in the water. The treed bog was slightly domed and within it surface water flow appeared to be towards the fen to the west. This flow was evidently not that of mineral rich groundwater, but rather poorer ombrotrophic surface run off whose origin was likely rainwater. (Du Reitz, 1949; Gorham, 1957; Sjors, 1963; Heinselman, 1963 etc.). pH and nutrient content of water samples taken east of the fen confirmed this theory and were within the limits of ombrotrophy dictated by other studies of wetlands.

Rainfall tends to dilute the minerotrophy of sites along which water flow was concentrated. Samples of water taken along transects beginning north of the fen, along the conifer swamp, graminoid rich *Sphagnum* rich treed fen to graminoid fen gradient were less minerotrophic immediately after a heavy rainfall in June than they were after a period of drought in November. After heavy rainfall water tables tend to rise in all sites. Changes in level were most dramatic in the fen indicating that this was the site of greatest run off flow. The rapid drop in water level shortly after the rainfall indicated that the central fen site might be similar to lagg sites described by Paivanen (1968) and Dai et al. (1974). They determined that lagg sites carry most of the run off water after a rain. Water table fluctuation was also observed in the eastern region of the study area.

In ombrotrophic sites (zones 1 and 3) fluctuations were related to rainfall, but not significantly so. Bay (1966) concluded that degree of water table fluctuation is dependent upon precipitation, interception, and evapotranspiration. Effects of precipitation on fluctuations in water table level could be masked by high interception of rainfall by vegetation in the heavily treed zone 1 (treed bog) site and high levels of evapotranspiration in the hot, dry, less vegetated zone 3 (low shrub bog) site. Water table fluctuations in zones 1 and 3 could be further reduced by the state of humification of the underlying peat. The hydraulic conductivity of peat varies inversely with the degree of humification (Rycroft et al., 1975). Thus, the greater decomposition of peat in minerotrophic sites means that they can carry less water, consequently surface layers were frequently water logged, while in ombrotrophic sites the peat, which was less decomposed, can carry more water at depth, keeping surfaces dry, reducing the amplitude of water level fluctuations after rainfall, and inhibiting development of vegetation with high nutrient requirements.

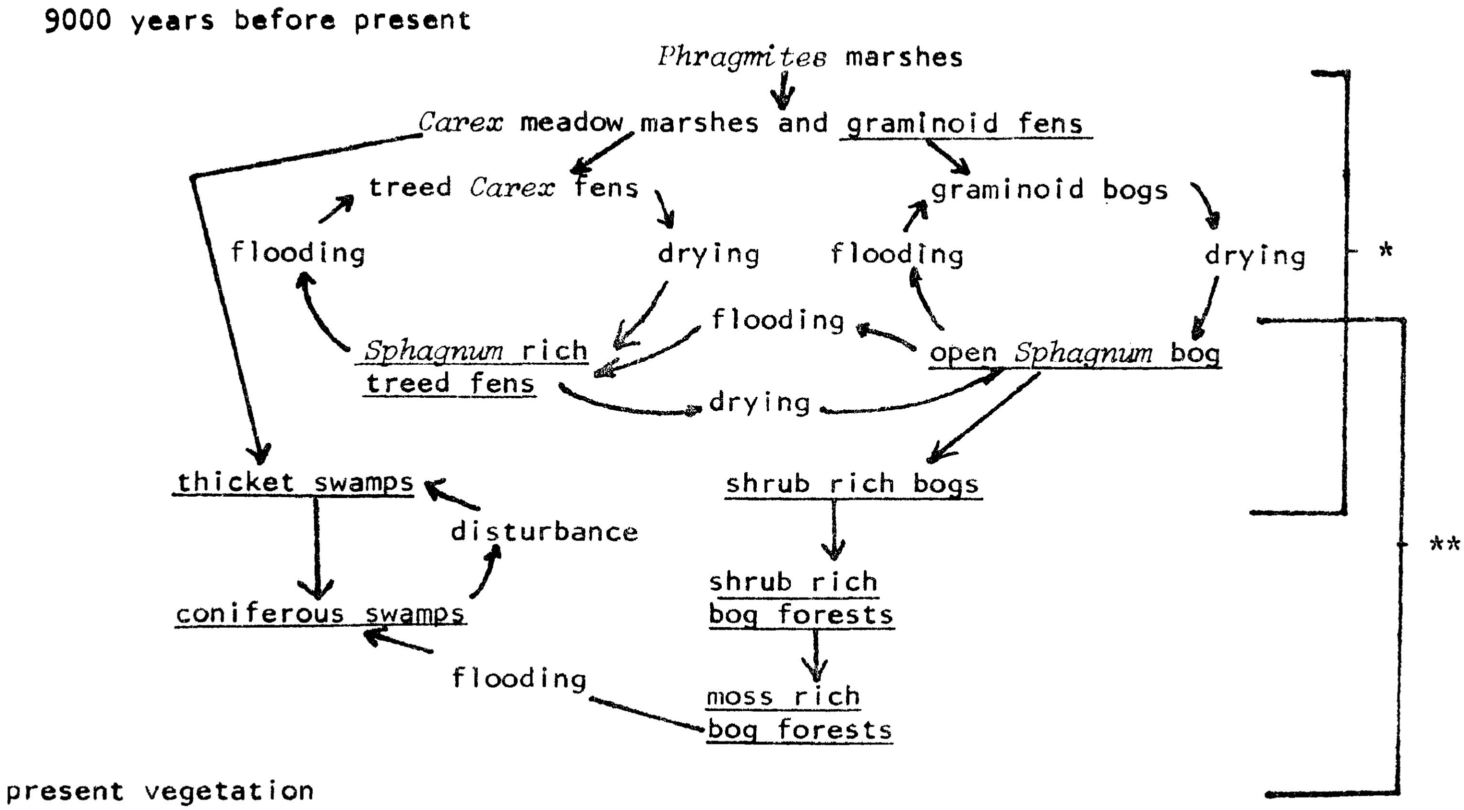
Water samples taken after some period of drought indicated that surface water run off from domed ombrotrophic sites dilutes the mineral concentration of waters in the fen, along its eastern boundary and that surface run off from minerotrophic sites west of the fen (zone 12 and 9) produced an area of strongly minerotrophic waters (zones 6, 7 and 8) on the western boundary of the fen. See Figure D-4. There appeared to be a concentration of nutrients in zone 10 as well and interestingly, there was also a repetition of zones 7 and 8 nearby. Unfortunately, these were not sampled, but would likely prove to be as rich as the central graminoid fen which terminates the gradient from conifer swamp, through thicket swamp from the west.

Within the study area there were two major types of sites, minerotrophic and ombrotrophic. This was demonstrated by the P.C.A. ordination of quadrats between axes composed of environmental data only. (See Figure R-121 and Table R-122.) Ordinations based upon floristics alone (Figures R-30 and R-52) do not indicate this, rather they indicated that there exists a continuum of sites following gradients of increasing soil pH, conductivity, calcium concentration and decreasing C:N ratios (see Figures R-117, R-118, R-119, R-120). Thus, conditions in the eastern portion of study area can be described as a continuum of vegetation communities which follow environmental gradients from poor to rich, from ombrotrophic to minerotrophic. Conditions in the northern and western portions of the study area indicated that there was a vegetation gradient from coniferous swamp to graminoid fen along which conditions are continuously minerotrophic. In minerotrophic sites surface water run off combines with groundwater flow to produce local very rich pockets of vegetation occupied by relic stands of *Phragmites communis*.

d) Succession and Dynamics

The development of vegetation structure within the study area has been clearly demonstrated to be related to the flow of groundwater within the peat bed. In this section it will be hypothesized that the initial development of the peat bed and the vegetation communities depositing the peat are also intimately related to groundwater flow and modified by climatic variations and disturbance over the 9000 year period during which William Bog developed its present floristic nature. Relationships are summarized in Figure D-5.

As the waters of Lake Minong receded, the shallow, sandy basin where William Bog developed was exposed, probably as a marshy area with poor drainage within which there were several channels where groundwater flow was directed. These channels ultimately drained south-west, into the Neebing River. Along the edges of these channels and slow moving drainageways algae and floating macrophytes invaded, followed rapidly by rooted emergent macrophytes such as *Phragmites communis*. These early colonizers slowed the flow of waters at the channel edges and facilitated the invasion of many *Carex* species producing a marsh type vegetation associated with the pools and slow moving waters within the abandoned lake basin. About the time this basin was exposed, and marshy development getting underway, the region's climate was becoming warmer and drier as the margins of the continental ice sheet receded northward (Saarnisto, 1974; Ritchie and Yarranton, 1978). Consequently, the basin began to dry up slightly and groundwater flow was reduced. At this time (approx. 8000 y.b.p.) the *Carex* marshes had established themselves along channels and in low lying sites producing a layer of sedgy peat which held the moisture and further slowed the movement of groundwater. Thus, the water table was carried with the expanding vegetation mat within which and at whose drier edges *Sphagnum* species were becoming established.



* lateral expansion of peatlands through paludification of nearby sandy lowlands

** development of raised swamps and bogs

Figure D-5 Succession and dynamic relationships of vegetation communities in William Bog, Thunder Bay, Ontario.

Communities underlined are present in the modern flora of William Bog.

Sphagna grow rapidly, and within small hummocks the water table was further dragged up through the capillary rise of water within the moss. All these processes resulted in the lateral expansion of the swamps and fens through paludification, producing a landscape which could survive the warming climate and yet maintain its wetland nature. Janssen (1968) noted a similar lateral expansion of *Typha* swamps through paludification during the same time period (8000-7000 y.b.p.) from evidence obtained through pollen stratigraphy of the Myrtle Lake peatland in northern Minnesota. Heinselman (1963, 1970) also proposed development based upon lateral expansion of the Lake Agassiz peatlands through paludification.

Where groundwater flow was concentrated graminoid fens established and maintained themselves in floating mats which insured, regardless of water level, adequate supply of nutrient rich waters. At the edges of these floating mats, where there was no flow of water, developing Sphagna, particularly *Sphagnum magellanicum* gradually overtook the landscape, dragging the water table with them. However, the waters associated with the Sphagna were becoming less rich and more acidic due to Sphagna's capacity to absorb cations (Gore and Allen, 1956). As hummock development proceeded the environment associated with the hummock tops became poorer and drier resulting in a less favourable environment for the wetter *Carex* species such as *Carex exilis* and *Carex gymnocrates* and a hospitable environment for species such as *Carex limosa*, *Carex chordorrhiza* and *Eriophorum angustifolium*. Thus, at the dry edges of graminoid fens, where there was no flow of mineral rich groundwater, graminoid bogs developed, eventually producing raised *Sphagnum* bogs with ombrotrophic tendencies. At the same time the graminoid fens present in areas of weaker groundwater flow were slowly being invaded by *Sphagnum magellanicum*, but remained minerotrophic in character due to seasonal surface flooding and subsurface flow of mineral rich waters.

Stratigraphic evidence from the study area upholds this theory of initial vegetation development. The central region of the study area consisted of a floating mat of graminoid peat based on sands, to the east peat deposition had been continuously Sphagna, and to the west the basal peat was *Sphagnum* for the first metre of deposition. Thus, it could be proposed that the fen developed within a groundwater drainage channel coming from the northeast. To the east and west of the channel development of ombrotrophic bogs proceeded as described. To the north, where there was a weakened flow of groundwater to the fen that was not confined in a channel *Sphagnum spp.* invasion proceeded, but ombrotrophy was not achieved. Thus, successional development proceeded along two possible routes depending upon the influence of groundwater (see Figure D-5).

Ombrotrophic Development

Diminishing groundwater influence facilitated the development of ombrotrophic vegetation as seen east of the fen. *Sphagnum spp.* produced large hummocks beginning the build up associated with domed bogs. *Sphagnum magellanicum* formed the base upon which

Sphagnum recurvum built up and, finally, *Sphagnum fuscum* produced the classic bog hummocks present in zone 2, 3 and 4 of the study area. M. Moss (1949) and E. Moss (1953) give detailed descriptions of bog succession in relation to *Sphagnum* hummock development which apply very well to William Bog. The open *Sphagnum* bog east of the fen was gradually invaded by shrubby species, particularly the Ericaceous shrubs which are common in zones 2, 3 and 4 today. Of these species *Andromeda glaucophylla* was likely an early colonizer of weakly minerotrophic damp hummocks of *Sphagnum magellanicum*. *Andromeda glaucophylla* has been recognized as an early colonizer of bogs by Dansereau and Segadas-Vianna (1952) and Janssen (1967) and occupied the richest sites of all the Ericaceous shrubs noted in the study area. *Kalmia polifolia* and *Vaccinium oxycoccos* invaded the drier hummock tops and *Chamaedaphne calyculata* the driest sites within the *Sphagnum* bog. Within this shrub zone hummock development proceeded. Millington (1954) noted that hummocks often developed on the leeward side of shrubs in open bogs, this was not evident in the study area. Bellamy and Rieley (1967) found that *Sphagnum fuscum* can rapidly shut off the influence of groundwater to surface vegetation and that 8 cm of *S. fuscum* peat over one square metre of rich fen, deposited over seven years, can transform that site to a poor bog. When conditions were correct ombrotrophy proceeded rapidly, which was exactly the case east of the fen. Small scale climatic variations keep the edges of the graminoid fen and shrub-rich *Sphagnum* bog in dynamic equilibrium, wet years tend to increase graminoid cover, dry years, shrub cover increases. Gradually, the shrubby hummocks were colonized by *Picea mariana* in the very dry sites and *Larix laricina* in richer sites. There was competition between the shrubs, the conifers, and the rapidly accumulating *Sphagnum* mass. This resulted in a cover of low, layered *Picea mariana* and shrubs whose increasing cover slowed the growth of *Sphagna* until finally, an overstorey became established. At the same time the site was becoming poorer, more acidic, completely out of the influence of groundwater, and dependent upon rainfall for its moisture and nutrients. This is the point at which the east side of the study area is today. In areas of high cover of *Picea mariana* shrub cover is low and *Dicranum polysetum* and *Pleurozium schreberi* dominate the understorey, in openings and areas of disturbance *Ledum groenlandicum* and *Chamaedaphne calyculata* are often present. *Ledum groenlandicum* is not present in the shrub rich portion of the bog.

This type of ombrotrophic development has been recognized by many authors. (Rigg, 1940; Moss, 1953; Segadas-Vianna, 1955; Sjors, 1963; Jaansen, 1967; Gauthier and Grandtner, 1975; etc.). Many studies in wetland succession also noted that there was a parallel development of minerotrophic sites along groundwater drainages (Heinselman, 1970; Vitt et al., 1975) that often predominated such that ombrotrophy became rare. Wildi (1978) modelled wetland development on varying slopes and found that this type of minerotrophy predominated downslope while, upslope ombrotrophy prevailed. In the study area minerotrophy predominated downslope, to the southwest.

Minerotrophic Development

Stratigraphy reveals that west of the fen deposition of *Sphagnum spp.* peat was interrupted after one metre of deposition and replaced with a mixed *Carex-Sphagnum* peat which remains until modern times. The ombrotrophic development of the fen was halted by an increase in minerotrophic development which was likely due to a shift towards a wetter climate approximately 3000 y.b.p. (Jaansen, 1968). Since the slope of the basin was towards the southwest ombrotrophic vegetation to the east was not affected. However, to the west, the open *Sphagnum* bog was flooded and subsequent invasion of *Carex spp.*, *Calamagrostis canadensis* and *Larix laricina* produced a mixture of vegetation with high nutrient requirements in low spots and ombrotrophic vegetation on the hummock summits. All this development on a slightly domed *Sphagnum spp.* peat bed resulted in a *Sphagnum* rich treed fen whose canopy has gradually closed in forming a thick tangle of *Picea mariana*, *Larix laricina* and *Thuja occidentalis* with a mixed understorey of both *Carex spp.* and Sphagna. Surface run off from this site was rich in nutrients because of the close subsurface flow of groundwater. This run off, in combination with groundwater flow down the graminoid fen meet in a rich thicket swamp, between the conifer swamp and the fen, in which deciduous shrubs of the genus *Salix* predominate with *Myrica gale*. This small zone (zone 9) was likely maintained by wildlife browsing the tips of *Larix laricina* and *Thuja occidentalis* at the edge of the conifer swamp. Winter observations confirm that these species are most frequently fed upon by rabbits, deer and moose. Since these species rely heavily upon apical growth, browsing allowed the deciduous understorey species to outcompete the conifers and form a shrub rich narrow band at the eastern edge of the conifer swamp. Continued browsing of the *Salix spp*. resulted in a low, thick growth of this species immediately west of a large animal trail which ran through the swamp thicket adjacent to the fen. Thus, this thicket zone was the result of disturbance by wildlife and, if that factor was removed, the coniferous swamp might progress into the fen and eventually cover it with swamp forest. This was evident on the north side of the fen where the coniferous swamp forest was out into the fen. Hummocks of *Sphagnum magellanicum* topped by well developed individuals of *Larix laricina* protrude into what was evidently graminoid fen vegetation. Subsurface groundwater flow will prevent this zone from proceeding through to ombrotrophic *Sphagnum* bog vegetation. This zone was a *Sphagnum* rich treed fen which has likely only recently invaded the graminoid fen because, the largest *Larix laricina* on the hummocks were an average of only 12 years old. The northern conifer swamp was bounded to the south by a large animal trail which was continuous with the previously mentioned trail through the thicket swamp. Perhaps the northern swamp boundary was maintained by browsing species such as moose, deer and rabbits and recent city expansion has resulted in a reduction in the number of such species. Consequently, there was reduced browsing pressure and a movement of the conifer swamp boundary towards the fen. City expansion has also increased the drainage within the study area and the development of *Sphagnum magellanicum* hummocks in the north (zone 11) and the east (zone 2) might be the immediate result. Both zones had ample floristic evidence indicating a much wetter nature in the past. Thus, the dynamic equilibrium between conifer swamp boundary and graminoid fen, which was partially maintained by disturbance from wildlife, has been shifted towards invasion of the graminoid fen by *Sphagnum* rich treed fen species because of the very recent influence of human beings and urban development.

Results of this study indicated that successional development in William Bog was not that of a traditional hydrarch succession (see Tansley, 1939) which culminates with a relatively stable closed canopy bog forest. Rather, succession can proceeded in either an ombrotrophic direction, when Sphagna can elevate the surface above the influence of mineral rich groundwater, or a minerotrophic direction, when surface or subsurface groundwater flow was too great for ombrotrophic development. Within these broad catagories boundaries between types were kept in a dynamic equilibrium, which was based upon climatic variations and disturbance. These equilibria appeared similar to cycles as defined by Watt (1947), but were likely not true cyclical processes. Thus, succession in William Bog was not undirectional, but rather, multidirectional and based upon local variations in drainage, climate and disturbance, a conclusion also reached by Sjors (1963) and Heinselman (1970) in their studies of wetland.

Conclusion

This study has successfully achieved the aims and objectives proposed in the Introduction. A portion of William Bog has been studied and described, thus preserving a record of its natural state before it is totally destroyed by urban expansion. The nature of floristic and environmental relationships in peatlands on the north shore of Lake Superior has been documented, providing the first record of such relationships in this region of northwestern Ontario. The relationship between vegetation type and environment in William Bog appears to be based upon the flow of mineral rich groundwaters through the peatland, such that in the study area minerotrophy dominates along drainageways producing a gradient of vegetation north and west of the fen which is apparently minerotrophic. East of the fen, away from groundwater flow, a domed ombrotrophic bog has developed at whose edges exists an environmental gradient from ombrotrophic to minerotrophic along which vegetation varies continuously from treed bog to graminoid fen. Peats east of the fen remain frozen longer than those west and north of the fen which are bathed in groundwater flow.

Based on the results of this study successional development in William Bog appears to be a complex process based upon the lateral paludification of a sandy basin within which vegetation development initially follows a minerotrophic series from *Phragmites communis* marsh to graminoid fen. Away from groundwater influence this series tends to proceed in an ombrotrophic direction. Along drainageways vegetation developes that is of a minerotrophic character. These developmental series are evident today in the domed ombrotrophic bogs which predominate in the northeastern portion of William Bog and the series of parallel fens running southwest in the central regions between which are coniferous swamps. The vegetation structure of William Bog is intimately related to its southwesterly slope which determines its ultimate drainage into the nearby Neebing River.

References Cited

Abramova,T.G. 1975. Geterotrofnyye kompleksyi stroyeniye torfyanoy zalezhi bolotnykh massivov klassa sklonov. (Hetertrophic complexes and the structure of the underlying peat deposits in slope mires.) Vestnik Leningradskogo Universiteta Geologiya Geografiya 6: 141-148.

Ahti,T. and R.L.Hepburn. 1967. Preliminary studies on woodland caribou range, especially on lichen stands, in Ontario. Ont. Dep. Lands For. Res. Rep. (Wildlife) No. 74. 134p.

Allington,K.R. 1961. The bogs of central Labrador-Ungava; an examination of their physical characteristics. Geogr. Ann. 43: 401-417.

Anon. 1974. Airport Handbook- Western Canada III Industrial Meteorology-Environment Canada. Atmospheric Environment Project 01174 (Thunder Bay A 94804).

Anrep,A. 1921. Investigation of peat bogs in Ontario. Geol. Sur. of Can. Summary Report 1921 part d.

Austin,M.P. and I.Noy-Meir. 1972. The problem of non-linearity in ordination: experiments with two gradient models. J. Ecol. 59: 763-773.

Austin,M.P. and L.Orloci. 1966. Geometric models in ecology. II An evaluation of some ordination techniques. J. Ecol. 54:217-227.

Baldwin,W.K.W. 1958. Plants of the Clay Belt. Nat. Mus. Can. Bull. No. 156. 324p.

Bannister,P. 1976. *Introduction to Physiological Plant Ecology*. Blackwell Scientific Publications, Oxford. 273p.

Barclay-Estrup,P. and C.H.Gimmingham. 1969. The description and interpretation of cyclical processes in a heath community. I Vegetational change in relation to the *Calluna* cycle. J. Ecol. 57:737-758.

Bay,R.R. 1966. Factors influencing soil-moisture relationships in undrained forest bogs*In* Proc. Int. Symp. For. Hydrology. 1965. Pergamon Press, Oxford.*335-343*.

Beals,E.W. 1973. Ordination: mathematical elegance and ecological naivete. J. Ecol. 61:23-35.

Bellamy,D.J. and J.Rieley. 1967. Ecological statistics of a miniature bog. Oikos 18:33-40.

Boatman,D.J. and R.W.Tomlinson. 1977. The Silver Flowe. II Features of the vegetation and stratigraphy of Birshie Bog and their bearing on pool formation. J. Ecol. 65:531-546.

Boelter,D.H. and E.S.Verry. 1977. Peatland and water in the northern lake states. U.S. Dep.Agric. For. Serv. Gen. Tech. Rep. N.C.-31.

Bouchard,A., S.Hay, and E.Rouleau. 1978. The vascular flora of St.Barbe South District, Newfoundland: An interpretation based on Biophysiographic area. Rhodora 80:228-287.

Bray,J.R. and J.T.Curtis. 1957.An ordination of upland forest communities of southern Wisconson. Ecol. Monogr. 27:325-349.

Brewer,P.G. and J.P.Riley. 1965. Automatic determination of nitrate in sea water. Deep Sea Research 12:765-772.

Brown,E., M.W.Skougstad, and M.J.Fishman. 1970. *Techniques of Water-Resources Investigations of the United States Geological Survey.* Chapter A1. Methods for collection and analysis of water samples for dissolved minerals and gases. Book 5, Laboratory Analysis. United States Government Printing Office, Washington.

Brown,R.J.E. 1967. Permafrost map of Canada. Div. Building Res., Nat. Res. Council of Canada, NRC 9769, and Geol. Survey of Canada, Map 1246.

Buell,M.F. and Buell,H.F. 1975. Moat bogs in the Itasca Park area, Minnesota. Bull. Torr. Bot. Club.102: 6-9.

Burnett,J.H. 1964. *The Vegetation of Scotland.* Oliver and Boyd. Edinburgh. 613 p.

Chapman, S.B. ed. 1976. *Methods in Plant Ecology.* Blackwell Scientific Publications. Oxford.

Clymo, R.S. 1963. Ion exchange in *Sphagnum* and its relation to bog ecology. Ann. Bot. 27: 309-324.

Conway, V.M. 1949. The bogs of central Minnesota. Ecol. Monograph 19: 173-206.

Cox, H.J. 1910. Frost and temperature conditions in cranberry marshes in Wisconson. U.S. Dept. Agric. Weather Bur. Bull. T.

Crum, H. 1976. *Mosses of the Great Lakes Forest.* Revised Ed. University Herbarium, University of Michigan, Ann Arbor Michigan 403 p.

Dai, T.S., V.S. Haavisto, and J.H.Sparling. 1974. Water level fluctuation in a northeastern Ontario peatland. Can. J. For. Res. 4: 76-81.

Dalla, Torre, and Harms. 1958. *Register zu de Dalla, Torre, et Harms. Genera Siphonogamarum ad systema Englerinum conscripta.* Akademische Druck-U-Verlagsanstalt. G.R.A.2/ Austria 568 p.

Dansereau, P. 1959. Phytogeographia Laurentiana. II The principal plant associations of the St.Lawrence Valley. Contrib. Inst. Bot. Univ. Montreal 75. 147p.

Dansereau, P. and F. Segadas-Vianna. 1952. Ecological study of the peat bogs of eastern North America. I Structure and evolution of vegetation. Can. J. Bot. 30:490-520.

Du Reitz, G.E. 1949. Main units and main limits in Swedish mire vegetation. Svensk. Bot. Tidskr. 43: 274-309.

Farrand, W.R. 1960. Former shorelines in western and northern Lake Superior basin. University of Michigan, Ph.D. thesis 226 p.

Fraser, J.W. 1961. A simple instrument shelter for use in forest ecology studies. Forest Research Branch Technical Note No. 113. Canada Department of Forestry. 10p.

Gauch, H.G. Jr., R.H. Whittaker and T.R. Wentworth. 1977. A comparative study of reciprocal averaging and other ordination techniques. J. Ecol. 65: 157-174.

Gauthier, R. 1971. Study of five peat-bogs in the lower St. Lawrence. I. Ecology. II. Stable litter peat. Quebec Dept. of Nat. Res. Mines Branch, special paper 10.

Gauthier, R. et M.M. Grandtner. 1975. Étude phytosociologique des tourbières du bas Saint Laurent, Quebéc. Naturaliste Canadien 102: 109-153.

Geiger, R. 1965. *The Climate Near the Ground.* Harvard University Press. Cambridge, Mass.

Gittens, R. 1969. The application of ordination techniques. *In: Ecological Aspects of the Mineral Nutrition of Plants.* (ed. by I.H. Rorison) Symp. Br. Ecol. Soc. 9: 37-66. Blackwell Scientific Publications.

Gleason, H.A. and A. Cronquist. 1963. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada.* D. van Nostrand Company. New York. 810.p.

Goodall, D.W. 1963. The continuum and the individualistic association. Vegetatio 11: 297-316.

Goodall, D.W. 1969. A procedure for the recognition of uncommon species combinations in sets of vegetation samples. Vegetatio 18: 19-35.

Gore, A.J.P. and S.E. Allen. 1956. Measurements of exchangable and total cation content for H^+, Na^+, K^+, Mg^{++}, Ca^{++}, and iron in high level blanket peat. Oikos 7: 48-55.

Gorham, E. 1956. The ionic composition of some bog and fen waters in the English Lake District. J. Ecol. 44: 142-152.

Gorham, E. 1957. The development of peatlands. Quart. Rev. Biol. 32: 145-166.

Gorham, E. 1967. Some chemical aspects of wetland ecology. Proc. 12th Muskeg Res. Conf. 1966. Nat. Res. Counc. Can. Tech. Memo. No. 90. p.20-30.

Gorham, E. and W.H. Pearsall. 1956. Acidity, specific conductivity and calcium content of some bog and fen waters in northern Britain. J. Ecol. 44: 129-141.

Green, B.H. and M.C. Pearson. 1968. The ecology of Wybunbury Moss, Cheshire. I. The present vegetation and some physical, chemical, and historical factors controlling its nature and distribution. J. Ecol.56: 245-267.

Greig-Smith, P. 1964. *Quantitative Plant Ecology*. Butterworth and Co. London.

Greig-Smith, P., M.P. Austin, and T.C. Whitmore. 1967. The application of quantitative methods to vegetation survey. I. Association analysis and principal component ordination of rain forest. J. Ecol. 55: 483-503.

Hanawalt, R.B. and J.E.Steckel. 1967. Automated distillation from soil suspensions or coloured solutions. *In: Automation in Analytical Chemistry, Technicon Symp. 1967*. Volume I. Medical Inc. White Plains, New York.

Hare, F.K. 1969. Climate and zonal divisions of the Boreal forest formation in eastern Canada. *In: Vegetation, Soils and Wildlife*. Process and Method in Canadian Geography. Metheun Publ. Toronto.

Heikurainen, L. 1954 . Havaintoja metsaujutuksen vaikutksesta turpeen lampotalouteen. Metsa Aikak. I: 31-34.

Heikurainen, L. 1960. *Metsa Ojitus ja sen perusteet*. Chapter VII Porvoo, Helsinki.

Heinselman, M. 1963. Forest sites, bog processes and peatland types in the glacial Lake Agassiz Region, Minnesota. Ecol. Monograph 33: 327-374.

Heinselman, M. 1970. Landscape evolution, peatland types , and the environment in the Lake Agassiz Peatlands Natural Area, Minnesorta. Ecol. Monograph 40: 235-261.

Hesse, P.R. 1971. *A Textbook of Soil Chemical Analysis*. John Murray (Publishers) Ltd. 520 p.

Janssen, C.R. 1967. A floristic study of forests and bog vegetation, northwestern Minnesota. Ecology 48: 751-764.

Janssen, C.R. 1968. Myrtle Lake: a late and post glacial pollen diagram from northern Minnesota. Can. J. Bot. 46: 1397-1408.

Jeglum, J.K. 1971. Plant indicators of pH and water levels in peatlands of Candle Lake Saskatchewan. Can. J. Bot. 49: 1661-1676.

Jeglum, J.K. 1972. Boreal forest wetlands near Candle Lake central Saskatchewan. I. Vegetation. The Musk Ox 11:41-58.

Jeglum, J.K. 1973 . Boreal forest wetlands near Candle Lake central Saskatchewan. II. Relationships of vegetational variation to major environmental gradients. The Musk Ox 12: 32-48.

Jeglum, J.K. and A.N.Boissonneau. 1977. Air photo interpretation of wetlands, Northern Clay Section, Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Report 0-X-269 44 p.

Jeglum, J.K., A.N. Boissonneau and V.F. Haavisto. 1974. Toward a wetland classification for Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep.0-X-215 54 p.

Johnson, E.A. 1977a. A multivariate analysis of the niches of plant populations in raised bogs. Can. J. Bot. 55: 1201-1210.

Johnson, E.A. 1977b. A multivariate analysis of the niches of plant populations in raised bogs. II. Niche width and overlap. Can. J. Bot. 55: 1211-1220.

Judge, S. 1978. Parkdale decision: A classic planning dilema. Thunder Bay Chronical Journal, August 26, 1978.

Keatinge, T.H. 1975. Plant community dynamics in wet heathland. J. Ecol. 63:163 - 172.

Kershaw, K.A. 1973. *Quantitative and Dynamic Plant Ecology*. Edward Arnold (Publishers) Limited, London. 308 p.

Ketcheson, D.E. and J.K.Jeglum. 1972. Estimates of black spruce and peatland areas in Ontario. Can. For. Serv. Sault Ste. Marie, Ont. Inf. Rep. 0-X-172. 24 p.

Knollenberg, R. 1964. The distribution of string bogs in central Canada in relation to climate. Univ. Wisc. Tech. Rep. No. 14. 44 p.

Kulcznski, S. 1949. Peat bogs of Polesie. Mem. Acad. Sci. Cracovie B. 1-356.

Lambert, J.M. and M.B. Dale. 1964. The use of statistics in phytosociology. Adv. Ecol. Res. 2: 59-99.

Lewis, F.J., E.S. Dowding, and E.H. Moss. 1928. The swamp, moor, and bog forest vegetation of central Alberta. J. Ecol. 16: 19-70.

Lewis, F.J., J. Francais, and E.S. Dowding. 1926. The vegetation and retrogressive changes in peat areas (muskegs) in central Alberta. J. Ecol. 14: 317-341.

Longley, R.W. and M. Louis-Byne. 1967. Frost hollows in west central Alberta, Canada Dept. Transport, Meteorological Branch, Circ. 4532.

Malmer, N. 1962. Studies on mire vegetation in the archaean area of southwestern Gotaland (south Sweden). Opera Bot. 7: 322 p.

McEwen, J.K. 1966. An effect of *Sphagnum* on the growth of black spruce. For. Chron. 42: 175-183.

Millington, R.J. 1954. *Sphagnum* bogs of the New England plateau, New South Wales. J. Ecol. 42: 328-344.

Moore, P.D. and D.J. Bellamy. 1974. *Peatlands*. Unwin Brothers Ltd. Surrey, England.

Moss, E.H. 1953. Marsh and bog vegetation in northwestern Alberta. Can. J. Bot. 31: 448-470.

Moss, M. 1949. Taxonomic and ecological studies of *Sphagnum* species and bogs of Alberta. Unpublished thesis. Univ. of West Ont. London, May 1949.

Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley and Sons. New York. 547 p.

Nie, N.H., C.H. Hill, J.G.Jenkins, K.Steinbrenner, and D.H. Bent.1975. *Statistical Package for the Social Sciences.*, Second ed. McGraw-Hill, New York.

Orloci, L. 1966. Geometric models in ecology. I.The theory and application of some ordination methods. J. Ecol. 54: 193-215.

Paivanen, J. 1968 . Pohavesipinta ja turpeen vesipitoisuus rahkamattaisella lyhytkortisella nevella.(Ground water level and water content of peat in an open low-sedge swamp with *Sphagnum fuscum* hummocks.) Suo 19: 17-24.

Pearce, S.C. 1969. Multivariate techniques of use in biological research. Exp. Agr. 5: 67-77.

Penman, H.L. 1963. *Vegetation and Hydrology.* Technical communication No. 53. Commonwealth Bureau of Soils, Harpenden. Commonwealth Agricultural Bureau, Central Sales, Farnham Royal, Bucks, England.

Peterson, E.B. 1965. Inhibition of black spruce primary roots by a water soluble substance in *Kalmia angustifolia.* Forest Science 11: 473-479.

Platt, R.B. and J.F. Griffiths. 1964. *Environmental Measurement and Interpretation.* Reinhold Publishing Corporation, New York. 235 p.

Porslid, A.E. 1944. Notes from a Labrador peat bog. Can. Field Nat. 58: 4-6.

Potzger, J.E. 1953. Nineteen bogs from southern Quebec. Can. J. Bot. 31: 383-401.

Potzger, J.E. and A. Courtmanche. 1954 . Bog and lake studies in the Laurention Shield in Mont-Tremblant Park, Quebec. Can. J. Bot. 32: 549-560.

Pollett, F.C. and P.B. Bridgewater. 1973. Phytosociology of peatlands in central Newfoundland. Can. J. For. Res. 3: 433-442.

Pollett, F.C., P.B. Bridgewater, and W.J. Meades. 1970. A classification of peatlands in central Newfoundland. For. Res. Lab. Inf. Rep. N-36, St. John's Newfoundland. 69 p.

Pye, E.G.. 1962. Geology and scenery along the north shore of Lake Superior, Ontario. Ont. Dept. of Mines. Geological Circular No. 10.

Radforth, N.W. 1958. Organic terrain organization from the air. Handbook No. 2. Defence Research Board, Dept. of National Defence, Ottawa. 124 p.

Radforth, N.W. and C.O. Brawner. eds. 1977. *Muskeg and the Northern Environment in Canada.* University of Toronto Press. 399 p.

Rigg, G.B. 1925. Some *Sphagnum* bogs of the north Pacific coast of America. Ecology 6: 260-278.

Rigg, G.B.. 1940. Development of *Sphagnum* bogs of the Atlantic coast, the interior, and the Pacific coast. Amer. J. Bot. 27: 1-14.

Rigg, G.B. 1947. Soil and air temperature in a *Sphagnum* bog of the Pacific coast of North America. Amer. J. Bot. 34: 462-469.

Rinne, R.J. 1976. Microclimatology Report. Unpublished typescript. Lakehead University. 78 p.

Ritchie, J.C. 1957. The vegetation of northern Manitoba. II. A prisere on the Hudson Bay lowlands. Ecology 38: 429-435.

Ritchie, J.C. 1959. The vegetation of northern Manitoba. III. Studies in the subartic . Artic Institute of North America Technical Paper No. 3. 55 p.

Ritchie, J.C. 1960a The vegetation of northern Manitoba. VI. The lower Hayes River region. Can. J. Bot. 38: 769-788.

Ritchie, J.C. 1960b. The vegetation of northern Manitoba. V. Establishing the major zonation. Artic 13: 211- 229.

Ritchie, J.C. 1962. A geobotanical survey of northern Manitoba. Artic Institute of North America Technical Paper No. 9.

Ritchie, J.C. and G.A. Yarranton. 1978. The late-quaternary history of the boreal forest of central Canada, based upon standard pollen stratigraphy and principal components analysis. J. Ecol. 66: 199-211.

Rowe, J.S. 1972. Forest Regions of Canada. Can. For. Serv. Publ. No. 1300 172 p.

Rowe, J.S. and G.W. Scotter. 1973. Fire in the boreal forest. Quat. Res. 3: 444-464.

Rowe, J.S., D.Spittlehouse, E. Johnson, and M.Jasieniuk. 1975. Fire studies in the upper MacKenzie Valley and adjacent Precanbrian Uplands. DINA Publication No. QS-8045-000-EE-A1.

Ruel, M., S.Chornet, B. Coupal, P.Aitcin, and M.Cossette. 1977. Industrial utilization of peat. *In: Muskeg and the Northern Environment in Canada*. ed. Radforth and Brawner. University of Toronto Press. 221-246.

Rycroft, E.W., D.J.A. Williams, and H.A.P. Ingram. 1975. The transmission of water through peat. J. Ecol. 63: 535-568.

Saarnisto, M. 1974. The deglaciation of the Lake Superior region and its climatic implications. Quaternary Research 4: 316- 339.

Schwintzer, C.R. 1978. Vegetation and nutrient status of northern Michigan fens. Can. J. Bot. 56: 3044-3051.

Segadas-Vianna, F. 1955. Ecological study of the peat bogs of North America. II. The *Chamaedaphne calyculata* community in Quebec and Ontario. Can. J. Bot. 33: 647-684.

Sjors, H. 1950. On the relation between vegetation and electrolytes in north Swedish mire waters.. Oikos 2: 241-300.

Sjors, H. 1961 . Forest and peatland at Hawley Lake, northern Ontario. Nat. Mus. Can. Bull 171. (Bio. Ser. No.64; Contributions to Botany, 1959) 1-31.

Sjors, H. 1963. Bogs and fens on the Attawapiskat River, northern Ontario. Nat. Mus. Can. Bull. 186: 45-133.

Sorenson, T.A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Biol. Skr. K. Dan Vidensk. Selsk. 5:1-34.

Sparling, J.H. 1966. Studies on the relationship between water movement and water chemistry in mires. Can. J. Bot. 44:747-758.

Stanek, W. 1977. Classification of muskeg. *In: Muskeg and the Northern Environment in Canada.* eds. Radforth and Brawner. University of Toronto Press. 399 p.

Stanek, W. and V.J. Krajina. 1964. Preliminary report on some ecosystems of the western coast on Vancouver Island. *In: Ecology of the Forests of the Pacific Northwest.* ed. V.J. Krajina. (Progress Report Univ. British Columbia, 1964) 57-66.

Stotler, R. and B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80:405-428.

Stringer, W.P. and M.H. Stringer. 1973. Studies on the bryophytes of southern Manitoba. VII. Distribution of terrestrial bryophytes in a black spruce bog in Bird's Hill Provincial Park. The Bryologist 76: 252-259.

Tansley, A.G. 1939. *The British Islands and their Vegetation.* Cambridge.

Thornthwaite, C.W. 1948. An approach toward a rational classification of climate. Geol. Rev. 38:55-94.

Tilton, D.L. 1977. Seasonal growth and foliar nutrients of *Larix laricina* in three wetlant ecosystems. Can. J. Bot. 55: 1291-1298.

Transeau, E.N. 1905. The bogs and bog flora of the Huron River Valley. Bot. Gaz: 351-377.

Vitt, D.H., P. Achuff and R.E. Andrus. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Can. J. Bot. 53: 2776-2795.

Vitt, D.H. and N.G. Slack. 1975. An analysis of the vegetation of *Sphagnum* dominated kettle-hole bogs in relation to environmental gradients. Can. J. Bot. 53: 332-359.

von Post, L. 1924. Das genetische System der organogen Bildungen Schwedens. Com. Int. Ped. IV. Comm. (Helsinki) 22: 287-304.

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

Walker, D. and P.M. Walker. 1961. Stratigraphic evidence of regeneration in some Irish bogs. J. Ecol. 49: 169-200.

Ward, S.D. 1970. The phytosociology of *Calluna-Arctostaphylaos* heaths in Scotland and Scandinavia. I. Dinnet Moor, Aberdeenshire. J. Ecol. 58: 847-863.

Watt, A.S. 1947. Pattern and process in the plant community. J. Ecol 43:490-506.

White, K.L. 1965. Shrub-carrs of southeastern Wisconson. Ecology 46: 286-304.

Whittaker, R.H. 1967. Gradient analysis of vegetation. Biol. Rev. 42: 207-264.

Whittaker, R.H. 1973. *Ordination and classification of communities. Handbook of Vegetation Science Part V.* Reinhold Tuxen ed. in chief. Dr. W Junk b.v. Publishers. 737 p.

Wildi, O. 1978. Simulating the development of peat bogs. Vegetatio 37: 1-17.

Williams, G.P. 1968. The thermal regime of a *Sphagnum* peat bog. Proc. 3rd Int. Peat Cong. Quebec. Canada.

Williams, W.T. and J.M. Lambert. 1959. Multivariate methods in plant ecology. I. Association analysis in plant communities . J. Ecol. 47: 83-101.

Wilson, R. 1970. Factors influencing distribution of aquatic macrophytes in a small northwestern Ontario lake. unpublished Master of Science thesis. Lakehead University, Thunder Bay, Ontario. 172 p.

Zoltai, S.C. 1963. Glacial features of the Canadian Lakehead area. Can. Geograph. 5: 101-115.

Zoltai, S.C. 1972. Palsas and peat plateaus in central Manitoba and Saskatchchewan. Can. J. For. Res. 2: 291-302.

Zoltai, S.C., F.C.Pollett, J.K. Jeglum, and G.B. Adams. 1974. Developement of a wetland classification for Canada. Proc. 4th North Amer. For. Soils Conf. Quebec City, Aug. 1973.

Zumberge, J.H. and J.E. Potzger. 1956. Late Wisconson chronology of the Lake Michigan basin correlated with pollen studies. Geol. Soc. Amer. Bull. 67: 271-288.

Appendix

The following section consists of raw data sheets containing data not otherwise listed in the body of the thesis.

Appendix Ia and Ib Percent cover of species sampled by point quadrats along level transect of the study area.
Topographic profiles of five selected *Sphagnum* spp, hummocks.

Appendix Ia- Percent cover of species measured over E-W transect determined as the percent of total hits possible in a 3 m section of the transect. Transect consists of 37 of such 3m sections.

Appendix Ib- Percent cover of species measured over W-E transects of selected *Sphagnum* hummocks . Determined as the percent of total hits in one of three elevation classes (0-200mm: 200-400mm: 401 plusmm) Taken every 2 cm along transect
Hummocks sampled in East muskeg, east transition, fen, west transition, west muskeg.

- Topographic profiles of above hummocks determined from the amount of pin remaining above sample frame (see Methods- Vegetation) taken every 2 cm.

Appendix II

Climate data collected from William Bog during 1977 and 1978. Includes rainfall, relative humidity, water table and peat mat fluctuations temperature maxima and minima in muskeg, transition, and fen sites at ground level and 1 m above ground, temperatures within and above *Sphagnum* spp. hummocks and snow depth measurements.

Appendix III Water and Soils

Raw data not included in body of thesis.
- water pH June 1978
- moist peat pH November 1978
- von Post humification of peat
- percent loss on ignition of peat
- available nitrogen of peat (ammonium and nitrate) transects A and F only.

Total cover along leveled transect in William Bog

AUGUST 1978.

% hits/3m. frame E → W — 1110 point quadrats taken every 10 cm. Taken over 37 3 metre sections

Species (p.286.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Carex trisperma	63	6.6	13.3	3.3	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex chordorrhiza	0	0	0	0	6.6	10	23.3	0	3.3	3.3	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.6	0	0	0	0	10	3.3	0	0	3.3	0
Carex limosa	6.6	3.3	0	6.6	0	10	10	10	10	33.3	10	20	46.6	20	23.3	56.6	33.3	30	56.6	33.3	60	46.6	76.6	83.3	73.3	43.3	33.3	26.6	23.3	13.3	50	36.6	70	50	50	20	6.6
Carex lasiocarpa 175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.6	6.6	3.3	3.3	0			0	0	0	6.6	3.3	3.3	0
Carex exilis	0	0	0	0	0	0	0	0	0	0	16.6	26.6	23.3	20	30	10	10	3.3	0	0	10	26.6	10	16.6	0	40	10	3.3	3.3	0	0	0	0	0	0	0	0
Eriophorum spissum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.6	30	23.3	3.3	0		0			0	0	0	0	3.3	3.3	0	0	0
Eriophorum coriaceum-vaginatum	0	0	3.3	3.3	10	6.6	6.6	20	10	30	10	3.3	13.3	20	6.6	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	3.3	3.3	0	0
Eriophorum angustifolium	0	0	0	0	0	0	0	0	0	0	3.3	3.3	0	0	0	0	0	0	6.6	3.3	3.3	0	3.3	0	0	0	0	0	0	0	0	0	0	6.6	0	0	0
Scirpus cespitosus	0	0	0	0	0	0	0	0	0	0	0	0	6.6	26.6	0	0	3.3	0	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum fluviatile	3.3	6.6	6.6	13.3	6.6	13.3	6.6	10	3.3	3.3	3.3	0	10	20	13.3	3.3	6.6	10	20	13.3	23.3	16.6	10	16.6	10	6.6	26.6	6.6	0	6.6	3	3.3	16.6	10	0	10	0
Drosera rotundifolia	0	0	0	3.3	3.3	0	0	0	0	6.6	0	3.3	0	0	0	0	0	0	0	0	0	3.3	3.3	0	0	0	6.6	3.3	6.6	0	6.6	0	0	10	3.3	6.6	0
Smilacina trifoliata	10	0	3.3	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0
Utricularia radiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.3	20	20	6.6	30	0	10	16.6	6.6	0	0	0	0	0	0	0	0	0	0	0
Menyanthes trifoliata	0	0	0	0	0	0	0	0	3.3	13.3	10	13.3	20	30	23.3	23.3	13.3	10	20	23.3	23.3	3.3	0	0	10	0	0		0	0	0	0	0	0	0	0	0
Kalmia polifolia	0	0	6.6	23.3	6.6	0	10	0	6.6	23.3	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0		0	0
Andromeda polifolia	0	0	6.6	0	6.6	0	6.6	10	0	0	13.3	13.3	3.3	10	0	0	6.6	13.3	0	20	6.6	0	26.6	13.3	10	10	0	0	16.6	0	0	3.3	6.6	6.6	23.3	30	3.3
Chamaedaphne calyculata	0	0	6.6	26.6	33.3	30	40	30	33.3	20	13.3	16.6	3.3	0	0	3.3	0	0	0	0	0	3.3	13.3	6.6	20	16.6	30	[illegible]	[illegible]	76.6	20	16.6	16.6	6.6	6.6	10	0
Ledum groenlandicum	20	23.3	6.6	0	3.3	3.3	6.6	0	6.6	3.3	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	6.6	0	10	0	0	3.3	0	3.3
Vaccinium oxycoccus	0	6.6	36.6	40	46.6	46.6	43.3	46.6	36.6	26.6	10	16.6	23.3	23.3	10	26.6	13.3	10	10	0	0	13.3	3.3	0	16.6	10	23.3	23.3	33.3	20	33.3	[illegible]	36.6	26.6	40	23.3	16.6
Picea mariana	36.6	23.3	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Myrica gale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		10	23.3	33.3	13.3	13.3	10	0	0	6.6	30	26.6
Tomenthypnum nitens	13.3	3.3	0	0	0	13.3	10	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	3.3	3.3	0
Tomenthypnum nitens var. falcifolium	13.3	3.3	0	3.3	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	3.3
Polytrichum juniperinum	0	0	23.3	10	23.3	0	13.3	3.3	13.3	0	20	16.6	0	0	0	0	0	0	0	0	0	0	0	0	3.3	10	10	10	20	3.3	33.3	0	0	0	0	0	0
Aulacomnium palustre	0	0	0	3.3	3.3	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.3	0	0	0	0	0	0	0	6.6	10	3.3
Sphagnum fuscum	16.6	3.3	26.6	30	43.3	3.3	16.6	56.6	60	33.3	43.3	43.3	3.3	0	0	0	0	0	0	0	0	0	0	0	0	13.3	0	33.3	0	26.6	0	20	0	0	3.3	0	0
Sphagnum magellanicum	23.3	10	10	40	26.6	30	33.3	26.6	16.6	30	0	3.3	0	0	40	13.3	16.6	0	0	0	0	0	0	0	10	10	40	20	46.6	33.3	26.6	26.6	3.3	40	16.6	0	0
Sphagnum recurvum	16.6	13.3	0	6.6	13.3	6.6	20	13.3	0	0	13.3	13.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.6	6.6	10	20	16.6	[illegible]	6.6	30	20	13.3	23.3
Campylium stellatum 177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	3.3	0	10	0	13.3	6.6	0	0	0	0
Drepanocladus exannulatus 174	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	16.6	3.3	0	0	0	0	0	0	0	0	0	0		0		0	
Sphagnum subsecundum	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0	6.6	10	20	0	0	3.3	0	0	0	0	0	0		0	0		

Measured as % of total number of hits in one* of 37 consecutive 3 m. sections

* usually a total of 30 hits in 3 metres ie. | 1 | 2 | 3 | etc See Methods section

Appendix Ia. % cover of species along level E→W transect of the study area (Determined from point quadrats taken every 10cm over 37 consecutive 3 m. samples.)

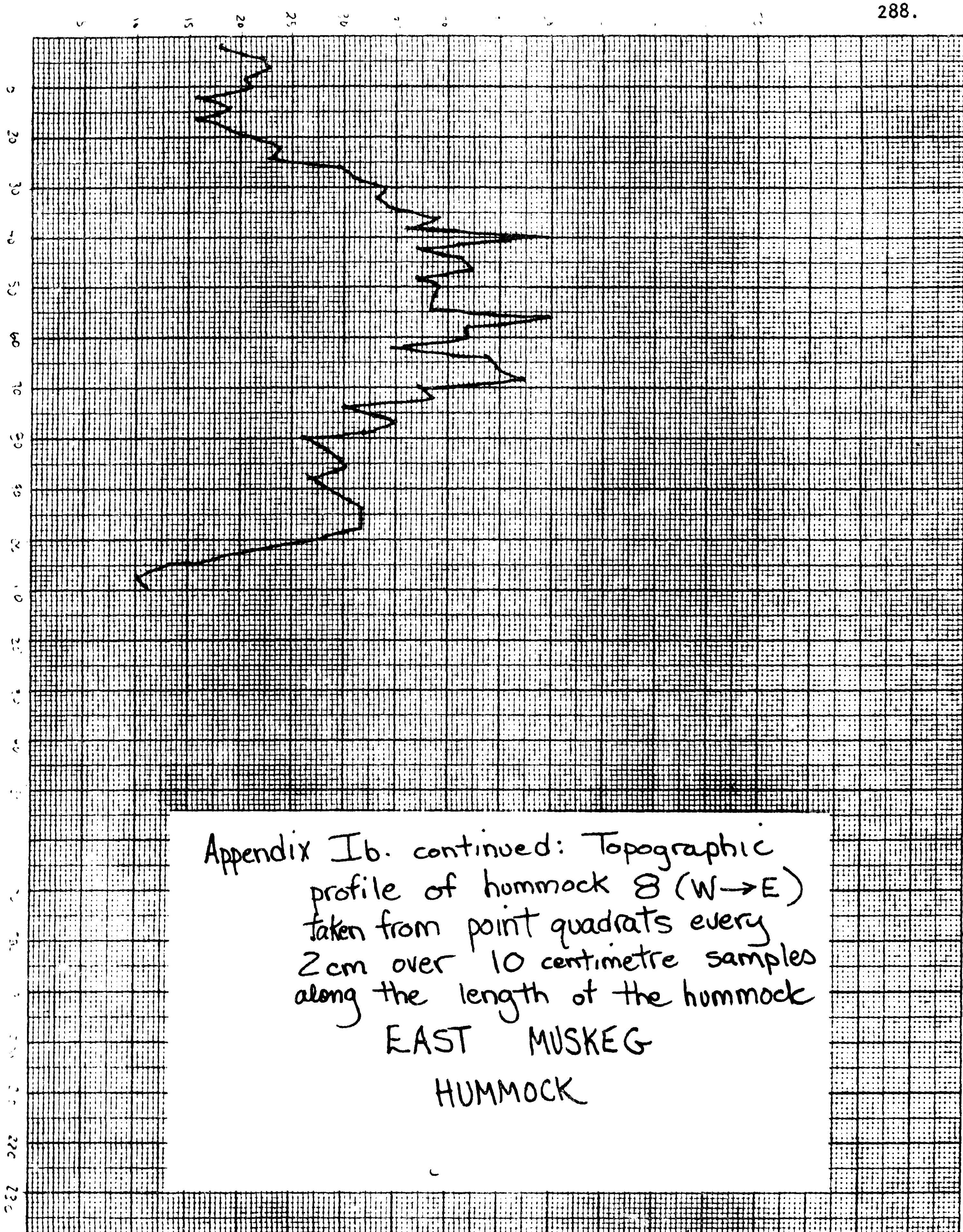
% COVER = % of hits in 3 m.

Hummock 8 EAST SIDE MUSKEG

% of hits of point quadrats taken every 2cm

Species	EV Class 1 (Elevation classes) 0-200 mm	COVER % of total hits	no. hits	Class 2 201-400 mm	COVER % of total hits	no. hits	Class 3 401 mm plus	COVER % of total hits	no. hits
Betula pumila	III	13.04	3	卌 卌 卌 卌 II	30.99	22	卌	35.71	5
Sphagnum recurvum	卌 I	26.09	6	卌	7.04	5			
Carex (169) trisperma	II	8.70	2	III	4.23	3			
Sphagnum magellanicum	III	13.04	3	卌 I	8.45	6			
Sphagnum capillaceum				卌	7.04	5	I	7.14	1
Ledum groenlandicum	III	13.04	3	III	4.23	3	I	7.14	1
...nen-nitens var falc.				卌 III	11.27	8			
Carex (175) lasiocarpa				III	4.23	3	I	7.14	1
Andromeda glaucophylla				I	1.41	1	I	7.14	1
Chamaedaphne calyculata	II	8.70	2	卌 I	8.46	6	II	14.28	2
Aulacomnium palustre				I	1.41	1	I	7.14	1
Kalmia polifolia				I	1.41	1			
blank				I	1.41	1			
Vacc. oxycoccus				III	4.23	3	I	7.14	1
Salix amygdaloides	IIII	17.59	4	III	4.23	3	I	7.14	1
			23			71			14

Appendix I b. % cover of species along an W→E transect of a *Sphagnum* spp. hommock. Point quadrats taken every 2cm and grouped by elevation.
Hummock 8 EAST MUSKEG



Appendix Ib. continued: Topographic profile of hummock 8 (W→E) taken from point quadrats every 2 cm over 10 centimetre samples along the length of the hummock

EAST MUSKEG

HUMMOCK

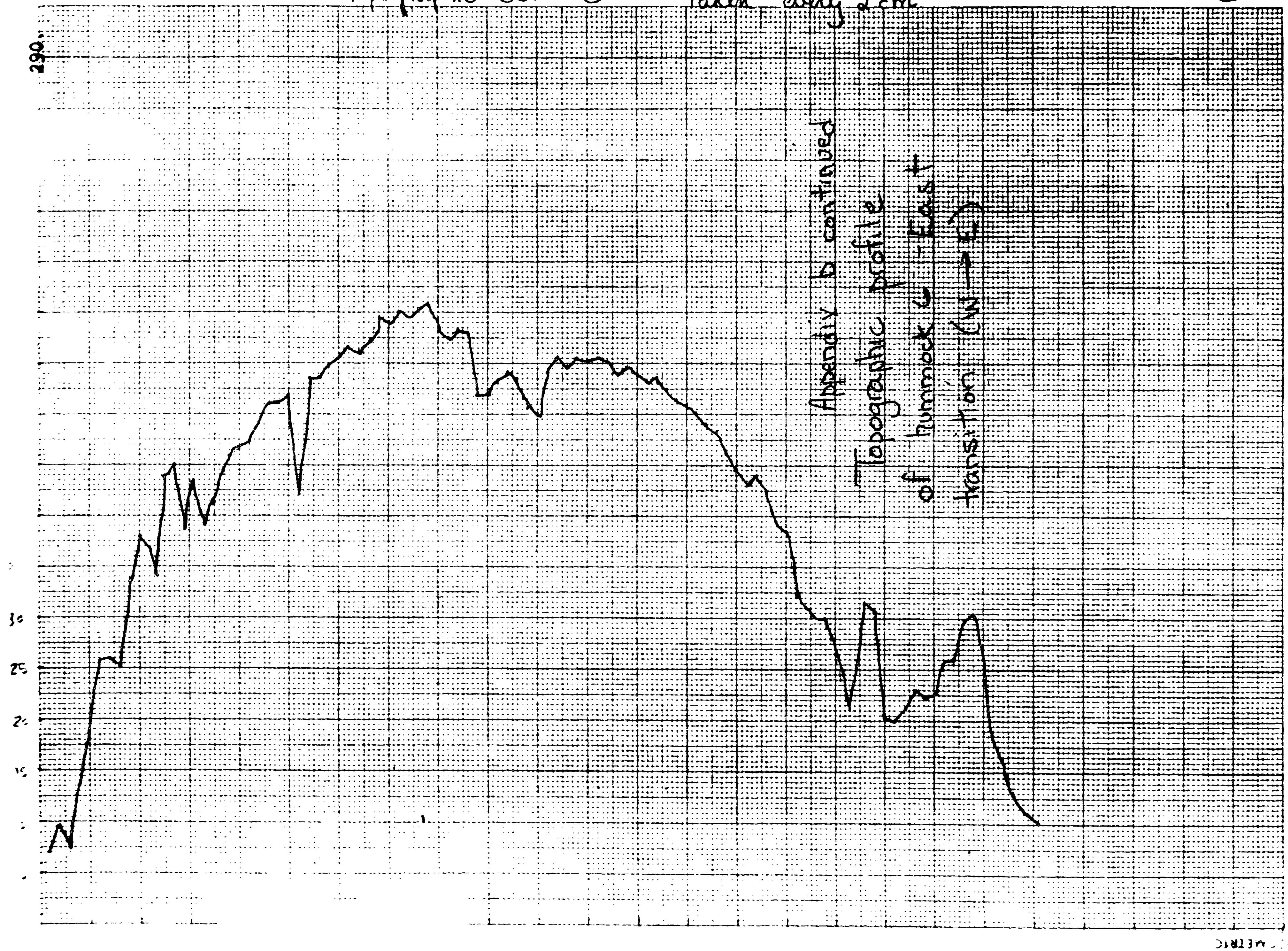
Hummock 6 EAST transition.

POINT QUADRATS TAKEN EVERY 2 cm

Appendix Ib continued.

	0-200 mm	COVER % total hits	no hits	201-400 mm	COVER %	# HITS	401 + plus mm	COVER %	# HITS
Kalmia polifolia	|	2.70	1	|	1.52	1	|||	2.01	3
Carex limosa	|||||||||	24.32	9	||	3.03	2			
Andromeda glaucophylla	||	5.40	2	|||||	7.58	5	||||||	4.03	6
Sphag. recurvum	|||	8.108	3	||||	6.06	4			
Equisetum fluviatile	||	5.40	2	|	1.52	1			
Eriophorum vag.	|	2.70	1	|||||	7.58	5			
Vaccinium oxycoccus	||||	10.81	4	|||||||	10.61	7	||||||	4.03	6
Sphagnum magellanicum	||	5.40	2	||||||	9.09	6	||	1.34	2
Chamaedaph. calyculata				|||||	7.58	5	[illegible]	18.79	28
Drosera rotundifolia				|	1.52	1	|	0.67	1
Carex exilis				|	1.52	1			
Sphagnum fuscum				||||	6.06	4	[illegible]	37.58	56
Menyanthes trifoliatum	|||	8.108	3				|||||||	4.69	7
Eriophorum angustifolium							|	0.67	1
Sphagnum capillaceum				|||||||||||||	19.69	13	|||	2.01	3
Polytrichum juniperinum				||||	6.06	4	[illegible]	20.13	30
Carex chordorrhiza							||||	2.68	4
Carex lasiocarpa							||	1.34	2
Carex lasiocarpa				|	1.52	1			
Scirpus hudsonianum				|||||	7.58	5			

Topographic outline taken every 2 cm Hummock 6 EAST TRANS. W → E



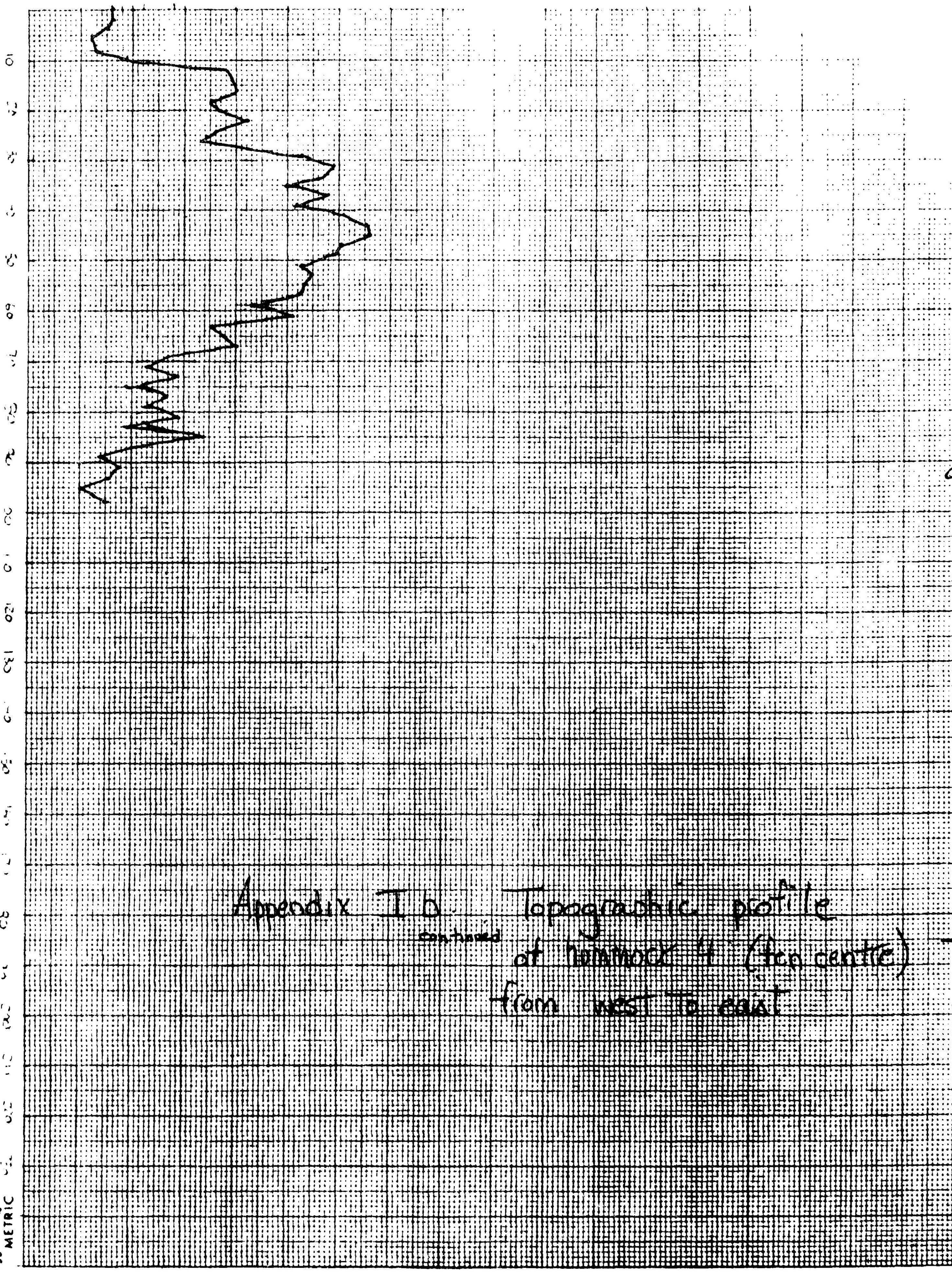
Appendix 6 continued
Topographic profile
of hummock 6 - East
transition (W → E)

Hummock 4 FEN CENTRE

% hits of quadrats taken every 2 cm and grouped by elevation

Species	elevation 0-200 mm tally	% COVER of total	# hits	201-400 tally	COVER %	# hits	401- plus tally	% COVER	# hits
Utricularia [illegible]	⁄⁄⁄⁄ |||	14.81	8						[illegible]
Eriophorum spissum	|||	5.55	3			2.04	1			
Carex exilis	||||	7.40	4	||	4.08	2			
Carex limosa	⁄⁄⁄⁄ ⁄⁄⁄⁄ ⁄⁄⁄⁄	2.77	15	⁄⁄⁄⁄ ⁄⁄⁄⁄ ||||	28.57	14			
Vaccinium oxycoccus	⁄⁄⁄⁄	9.25	5	⁄⁄⁄⁄	10.20	5			
Sphagnum magellanicum	⁄⁄⁄⁄ ⁄⁄⁄⁄ |||	24.07	13	⁄⁄⁄⁄ ⁄⁄⁄⁄ ||	24.48	12			
Equisetum fluviatile	||||	7.40	4	||	4.08	2			
Sphagnum recurvum	||	3.70	2	|||	6.12	3			
Drepanocladus (1-74) exannulatus						2.04	1			
Tomenth. nitens var. folia.				⁄⁄⁄⁄ |||	16.32	8			
Drosera rotundifolia						2.04	1			
Chamaedaphne calyculata			1.85	1						
Andromeda glaucophylla	|||	5.55	3						
			~~53~~ 54			49			

Appendix Ib continued - % COVER of species over a fen centre hummock from W → E



Appendix Ib continued Topographic profile of hummock 4 (top centre) from west to east

Hummock (2) West transition

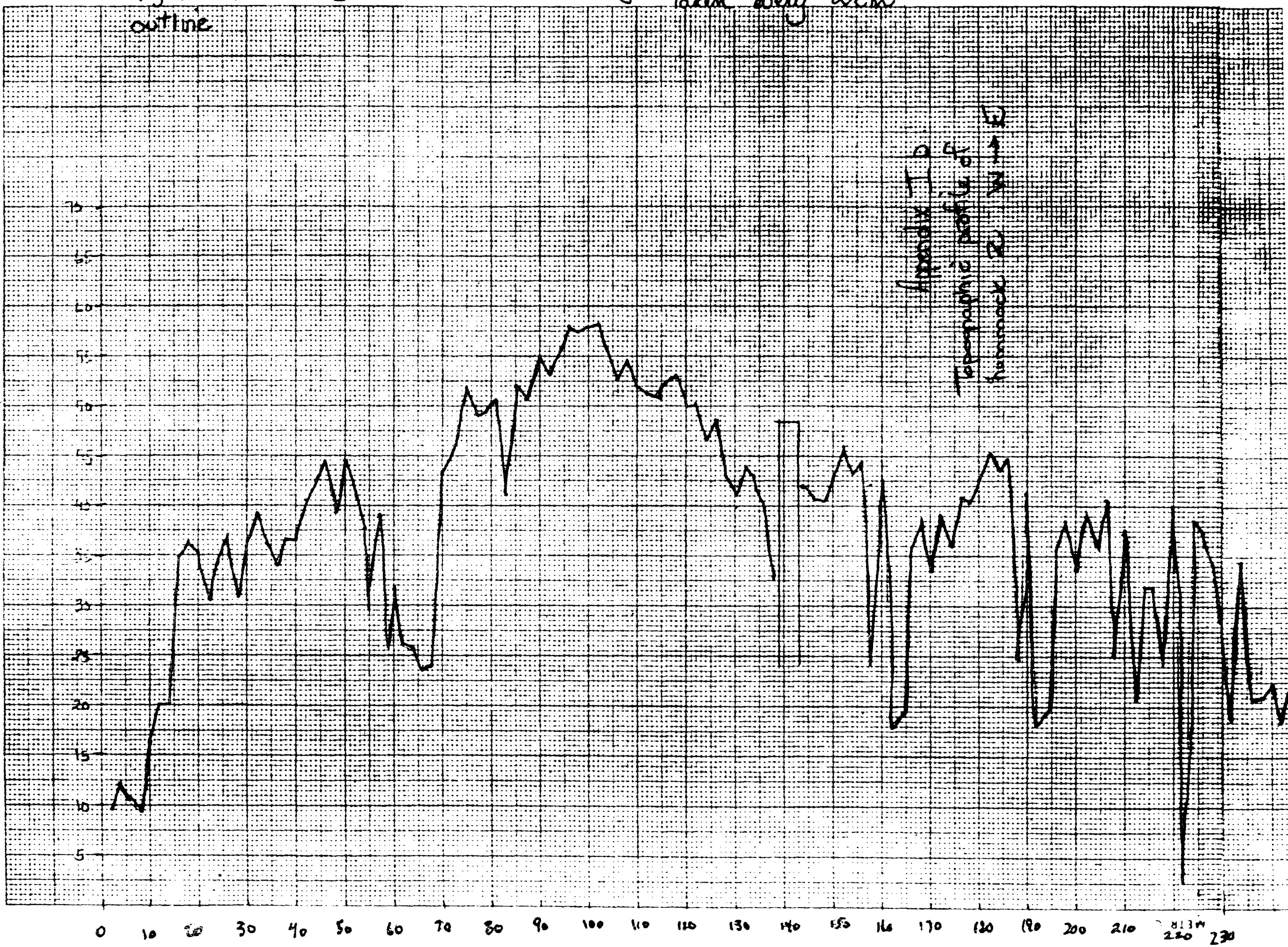
Percent total hits

ev class 1 0-200mm	ev class 2 201-400mm	ev class 3 401-600	Species
% COVER	% COVER	% COVER	
	1.71 %		Polytrichum juniperinum
40.74 %	26.49 %	8.16 %	Carex limosa
11.11 %	18.80 %	19.39 %	Chamaedaphne calyculata
7.4 %	6.84 %	1.02 %	Equisetum fluviatile
7.4 %	5.98 %	18.37 %	Sphagnum magellanicum
18.51 %	3.42 %		Carex exilis
	1.71 %		Tomenthypnum nitens
7.4 %	13.68	1.02	Sphagnum recurvum
	1.71		Campylium stellatum
	1.71		Sphagnum wulfianum
	4.27	4.08	Sphagnum capillaceum
	2.56	25.51	Sphagnum fuscum
	0.85	6.12	Phragmites communis
		2.04	Vaccinium oxycoccus
	1.71	5.10	Andromeda glaucophylla
	4.27	9.18	Kalmia polifolia
	5.98		Myrica gale
3.7			Calla palustris
3.7			Eriophorum sp.

Appendix Ib continued

% Cover of species from W→E over a West transitional hummock grouped by elevation class.

Topographic Hummock (2) Mature hummock in Phragmites fen on Westside Transition W → E
Taken every 2cm



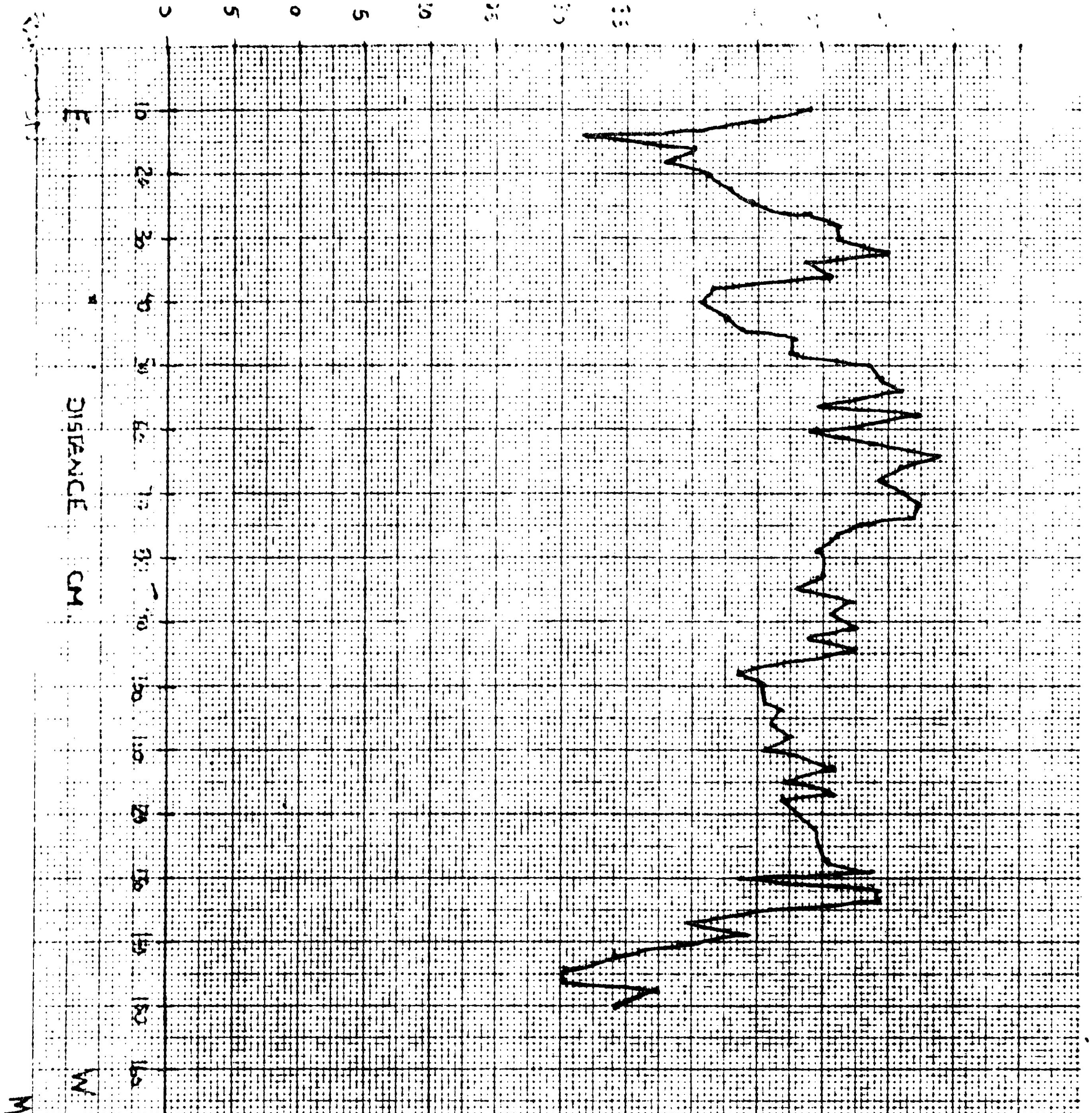
Hummock ① WEST MUSKEG

POINT QUADRATS TAKEN EVERY 2 cm grouped by elevation.

Species	elevation 0 – 200.0 mm	% hits	no. of hits	elevation 201 – 400 mm	% of hits	no. of hits	elevation 401 – 600		no. of hits
Carex lasiocarpa							||||	2.25	4
lix amygdaloides				|	5.00	1	[illegible]	13.55	24
uisetum fluviatile				||	10.00	2	||||	2.25	4
nilicina trifoliata				||	10.00	2	[illegible]	6.21	11
renthypnum nitens				|	5.00	1	|||	1.69	3
rex chordorrhiza							||||	2.25	4
accinium oxycoccus				|	5.00	1	[illegible]	11.27	20
rex limosa				||||	25.00	5	[illegible]	12.99	23
rosera rotundifolia							|||	1.69	3
nicera villosa							||||	2.25	4
rracenia purpurea							|	0.56	1
hagnum capillaceum				|	5.00	1	[illegible]	3.95	7
phagnum magellanicum							|	0.56	1
ulacomnium palustre							[illegible]	3.95	7
ndromeda glaucophylla							[illegible]	2.25	4
hamaedaphne calyculata							|	0.56	1
yrica gale				||||	20.00	4	[illegible]	9.10	17
phagnum recurvum							[illegible]		20
edum groenlandicum				|	15.00	3	[illegible]	18.07 2.83	7
Kalmia polifolia							|	1.12	2
					20				

Appendix Ib continued.

% cover of species in a west muskeg hummocks (hummock 1) grouped by elevation



Appendix I b.
Topographic profile
of hommock 1, West
muskeg (W → E)

TOPOGRAPHY OUTLINE
TAKEN EVERY
2 cm.

HUMMOCK 1 WEST
MUSKEG

Appendix II

Climatic data

William Bog climatic data

1" = 25.4 mm

M = Muskeg
T = transition
F = Fen

298.

DATE	Comments	RAIN (MM) Kley	Mat fluctuation	% RH M	% RH T	% RH F	EM MAX	EM Rdg	ET MAX	ET Rdg	EF MAX	EF Rdg
1978												
MAY 18	hot sunny 32°C, brisk breeze		—	23	31	31						
MAY 25	dull, bit of rain 15°C no wind.	4.1		54	51	58						
MAY 29	very foggy 52°F						—			45		82
JUNE 2	dull 15° no wind	41.4			—		—	—	48cm	45cm	71cm	68.
JUNE 5	sunny 20°F brisk breeze								45	44	65	65.
JUNE 7	thunderstorms 15°C no wind.	11.0		40	90	84	—	—	45	44	70	69
JUNE 8	sunny, brisk SE wind 15°C	3.9	30.5		—		—	—	40.3	42.7	65.2	65.2
JUNE 15	overcast, cool brisk NE wind 11°C	0	32.5	80	81	77	—	—	42.5	40.5	65.0	63.8
June 23	sunny, 20°C, brisk W wind	2.7	36cm	50	45	55	35.3	35.5	40.5	39.0	64	61.5
June 26	heavy rains	34.5	34				40.0	39.5	40	40	64	64
June 27	heavy rain		32									
June 30	overcast 22°C, NE breeze	26.3	34	67	70	74	41.0	40.0	43	40.5	66.5	65.0
July 8	overcast 20°C, showers	16.2	33	83	82	78	40	39	41	41	65	64
July 17	hot sunny 28°C NW breeze	19.7	35	60	71	79	40	38.0	41	40	65	63
July 25	hot sunny 27°C W breeze Thunderstorms	14.45	36	64	64	56	37.5	32.5	40.5	39	63.5	60.5
Aug 1	hot sunny 25°C NE breeze	13.4	36	60	68	65	32.5	31.0	37.8	35.7	59.8	57.5
Aug 7	hot sunny 29°C W breeze	5.4	35.6	53	58	59	31.0	29.5	35.5	33.0	56.5	55.7
Aug 14	hot, Lazy 32°C W breeze		35.5	58	60	58	29.6	29.5	33.3	33.2	56.0	55.8
AUG 21	hot sunny 27°C no wind (2 week Total)	39.3	35	75	66	71	29.6	29.5	35.1	34.0	58.1	56.5
AUG 28	dull all week. Choppy Sunny 20°C W. breeze	5.3	34.2	52	49	41	29.8	29.2	35.4	35.1	58.1	57.7
Sept 5	Mixed weather overcast 20°C	12.2	35.5	75	86	86	29.4	28.3	35.2	34.1	58.6	56.8
Sept 11	dull week, rain 13°C	12.2	34.6	100	100	86	28.5	28.0	35.6	35.5	58.5	58.5
Sept. 18	dull, choppy day 13°C	10.5	37.0	82	84	90	29.4	29.0	35.1	35.0	58.6	57.6
Sept. 25	A-1 day, 7°C, choppy week	5.8	37.0	82	79	76	28.9	28.0	35.1	34.1	58.4	56.5
Oct 3	fog, choppy week, 7°C	21	37.1	100	100	100	29.5	29.0	35.5	35.0	59.2	58.6
Oct 9	sunny, no wind. 13°C choppy week	4.6	36.5	100	94	94	24.6	28.9	35.1	35.1	59.4	59.5

William BOG CLIMATIC DATA continued.

Date	comments	PRECIP MM	Mat FLUC MM	% RH M	% RH T	% RH F	Water level (cm) EM My	EM Rdg	ET Mx	ET Rdg.	EF Mx.	EF Rdg
1978												
Oct. 16	overcast 9°C	5.2	373	—	—	—	296	294	353	353	606	600
Oct. 23	Sunny 2°C	0	386	—	—	—	29.5	29.0	353	346	600	598
Oct. 30	Snowy week, Indian summer day 15°C	0.6	380	60	48	52	280	274	358	342	607	596
Nov. 7	sunny 5°C frozen like apple crisp SW wind	.9	391	—	—	—	272	265	341	336	603	520
Nov. 14	overcast -1°C snow strong W wind	6.6	390	—	—	—	265	261	342	336	522	frozen

William Bog climatic data.

DAILY Temperature — mx-mn from Hygrothermograph. EAST TRANSITION 300.

Temp °C

Week 1978	comment	THUR MX	THUR MN	FRI MX	FRI MN	SAT MX	SAT MN	SUN MX	SUN MN	MON MX	MON MN	TUES MX	TUES MN	WED MX	WED MN	X̄ MAX	X̄ MIN
June 2	blue ink froze							17.8	6.1	21.1	1	29.8	3.5	13.5	6	20.5	4.2
June 8	thunderstorm	13.5	-1.5	13.5	-4	30.5	3.8	26	13.0	16	8	18.5	1	19.5	-1.5	19.6	2.4
June 15	cool, windy	24	1	17	9	28	8.5	25.5	6	27.5	9.8	22	11	20	8.5	23.4	7.7
June 22		26	-1	24.5	11	23.5	11	21	13	29.5	14	28	14	31.5	10.5	26.3	10.4
June 29	hot sunny	30.5	10.8	21.0	13.0	22	13.5	20	13.5	26	4	28.5	8.5	27	13	25	9.2
July 6	Foggy	27.5	14.5	32	11.5	28	10	17.7	8.6	20.0	5.8	23.3	6.1	20	18	24.1	9.2
July 13		21.5	12.8	25.8	11	22.5	7.3	24.4	8.4	29	14	30	9	26	8	25.6	10.4
July 20		24	5.5	24	10	21	10.5	29	8	—	—	30	12	29	10.5	26.2	7.0
July 27		23	3	21	1	—	—	22	9	25	5	33	18	24	6	24.6	7.0
AUG 3		31.5	7	26.5	5.5	28	1	28.5	-1	30	16.5	26.5	13.8	26.5	1.5	28.2	6.3
AUG 10		25.8	1.8	28.5	8.5	30.	8.5	25	13	33	14.5	28	19	21	16	27.3	11.6
AUG 17	rainy dull week -	20.5	14.5	27.5	15	22.2	7	26	0.5	27	8.5	22.5	14	15.5	11.5	23.1	10.1
AUG 24	(rainy dull week)	16.5	11.5	24	14	17	12	17.5	15.5	27	13.5	25	7	20	-1	21.0	10.4
AUG 31		24	-1	24.5	6	30.5	11	24	5	27	10.5	22.5	11	27	11	25.6	7.6
SEPT 7		15	12	17	8.5	14	8.5	17	10	16	12	14.5	8	12.5	8	15.1	9.6
Sept 14		19.5	10	19.5	7	-0.5	14	18	9.5	17	12	15	11	15	5	16.9	9.8
Sept. 21		16	1	19	-1.5	22	1.75	20	5	16	8	21	2	18	-1	18.9	2.6
Sept. 25		20	1	13	9	16	.5	17.5	9	-	-2.5	19	7	17	2	17.1	3.7
Oct 5		14	5	12.5	4	10	-2	17	-4.5	22	-2	20	0	14	11	15.6	1.6
12		10	-2	13.5	0	8	-3	mechanical				freeze-up				10.5	-1.6
19		and	frozen	ink						11	-5.5	13	4	10	4.5	11.3	4.6
26		8.5	-4	10	1	10	<-5*	11.5	<-5*	17.5	5	15	<-5*	17.5	-1	12.8	—
NOV 2		23.8	-4	17	2	9.5	-1.5	11	3	—	0	15	3.5	7.5	1	13.9	05
9		1.5	-3	froze	up -												
16																	

* temperatures below -5°C inaccurate

William Bog Climatic data

Daily relative humidity MAX-MINS

% RH from Hygrothermograph. EAST TRANSITIO

DATE 1978		THUR MAX	THUR MIN	FRI MAX	FRI MIN	SAT MAX	SAT MIN	SUN MAX	SUN MIN	MON MAX	MON MIN	TUES MAX	TUES MIN	WED MAX	WED MIN
JUNE	1							84	51	84	38	83.5	22	82	34
	8	85	40.5	84	31	76	38	82	34	72	37	86	30	85	30
	15	84	62	84	62	84	22	82	21	85	35	8[illegible]	58	86	34
	22	88	27	8[illegible]	31	85	52	82	60	82	43	81	39.5	82	27
	29	82	34	82	55	80	48	80	66	85	38	84	44	83	25.5
JULY	6	83	32	83	64	83	30	—	—	82	45	82	42	83	44
	13	84	40	84	43	84	62	84	26	—	—	84	38	81	25
	20	81	25	—	—	82	34	84	62	—	—	82	36	84	29
	27	81	25	—	—	81	25	82	34	84	37	80.5	34	81	32
AUG	3	72	42	80	30	84	26	85	3	78	41	81	32	84	28
	10	84	35	83	38	83	44	83	55	82	60	81	80	81	59
	17	78	53	82	33	83	28	83.5	40	82	62	81	42	84	66
	24	83	76	82	49	83	70	82	75.5	81	—	82	34	85	40
	31	83	42	83	56	83	28	84	46	83	62	83	60	82	57
SEPT	7	81	78	84	63	81	67	83	77	82	—	—	—	81.5	68
	14	86	52	84	58	87	—	85	—	81.5	4[illegible]	85	76	80.5	43
	21	84	40	84	38	84	36	85	36	78	42	84	40	85	33
	28	83	25	82	78	82	50	84	42	86	83	84	83	84	40
OCT	5	83	59	72	48	82	—								

William Bog
Climatic Data

Temperature °C MAX - MIN

DATE 1978		E. MUSKEG GROUND MAX	E. MUSKEG GROUND MIN	E. MUSKEG 1.0M MAX	E. MUSKEG 1.0M MIN	E. TRANSITION G MAX	E. TRANSITION G MIN	E. TRANSITION 1.0M MAX	E. TRANSITION 1.0M MIN	E. FEN G MAX	E. FEN G MIN	E. FEN 1.0m MAX	E. FEN 1.0m MIN
MAY	18												
	25												
	29												
JUNE	2	—	—	—	—	31.1	3.3	—	—	31.7	0		
	5												
	7	28	-03	33	-3	29	-3	21	-2	25	0	29	-2
	8												
	15	32	-6	32	-6	31	-4	27.5	-1	26	-3	26	-2
	23	33	-3	31	-3.5	29	-3	27	-0.5	26	0	26	-1
	26												
	27												
	30	36	6	34	8	33	8	32.5	10	31	11	32	10
JULY	8	34	3	32	5	32	4	30	7	32	6	32	4.5
	17	31.5	0	31	+1	31.5	3	~~25~~ 32	6	33	5.5	32	4.5
	25	34	1	32	3	29	4	28	18	29	7	30	5
AUG	1	33.5	-3	31	-1	26	-1	26	4	26	2	25	0
	7	31	-2	30	0	30	-1	28.5	6	30	2	26.5	1
	14	31	-3	31	-1	30	-1	26	0	28	2	28	0
	21	33	-2	32.5	0	30	1	29	0	28	1.5	32	0
	28	32	9	30	10	28.5	9.5	26	8.5	27	11	27	10
SEPT	5	30	-3	31	-2	30	2	29	7	30	0	29	0
	11	28	5.5	28	7	28	6	19	8	27	8	29	7
	18	19	-3.5	20	-3	21.5	-3	16	6	20	0	16	0
	25	23	-5	24	-4	25	-5	24	-4	23	-2.5	20	-4
OCT	3	21	-4	23	-3	23	-4	15	4	22.5	-2	20	-3
	9	17	-7	20.5	-6.5	21	-7.5	17.5	-5	20	-5	12	-6

William Bog CLIMATIC DATA
Temp °C MAX-MIN continued

Date 1978	E MUSK. 0 Mx	E MUSK. 0 Mn	E MUSK. 1.0 m Mx	E MUSK. 1.0 m Mn	E.TRANS 0 Mx	E.TRANS 0 Mn	E.TRANS 1.0 m Mx	E.TRANS 1.0 m Mn	E.FEN 0 Mx	E.FEN 0 Mn	E.FEN 1.0 m Mx	E.FEN 1.0 m Mn
Oct 16	18	-8	21	-7	21	-8	18	-7	23	-6	21	-7
Oct 23	21	-12	26	-11	26	-9	24	-8	26	-8	25	-8
Oct 30	13	-12	17	-11	17	-11	17	-10	17.5	-8	17.5	-10
Nov 7	15.5	-14.5	19	-13	20	-13.5	18.5	-12.5	11	-10	10	-12
Nov 14	13	-18.5	11.5	-17	15	-17	11	-9	13	-12	shook down.	

Temperatures in Sphagnum hummocks

Thermocouples °C

T = transition
M = muskeg
(for true temp. add 04. reference junction)

DATE			T-1	T-1	T-1	T-1	T-1	M-1	M-1	M-1	M-1	M-1	+0 T-1	↓ M-1
			EAST PLUG M-1, T-1											
		SWITCH POSITION	1	2	3	4	5	7	8	9	10	11	Ref	Ref
		DEPTH	0	-3	-15	-30	-50	0	-3	-15	-30	-50		
une 7	T-1 frozen, ate an auger	°C	—	—	—	—	—	15.5	15.5	7.0	0.5	0.45		16.5
UNE 8	East plug wet M-2 frozen	°C	—	—	—	—	—	—	—	—	—	—		—
UNE 15	M-2 still too frozen to plant	°C	17.8	12.5	5.5	0.0	0.0	14.8	13.0	6.3	0.3	-1.1	17.5	16.0
une 23	M-2 frozen still	°C	20.3	15.0	-0.2	-5.0	-4.0	19.5	16.2	~~15.5~~ 4.5	-4.5	0	20	26
une 30	M-2 planted, most still frozen	°C	22.5	21.0	8.0	3.2	1.0	21.8	21.0	6.7	0.1	-7.2	25	21
July 10		°C	28.3	23.5	9.5	5.0	3.8	26.0	23.5	8.2	0	-4.3	30	24
July 17		°C	31.2	25.2	11.0	7.3	7.5	30.3	25.0	10.3	0.1	-1.8	33	29
July 25	fen is drying out & humping up (hot dry: July 25 – Aug 14)		34	26	14.5	12.0	10.5	22.0	21.2	17.3	11.5	7.0	27	25
Aug 1	continued drying of fen		28	27.8	9.8	8.6	9.8	32.6	27.4	9.0	2.5	0.25	29	23
AUG 7			27.8	24.2	4.0	0	2.3	30	24.5	12.5	1.4	-1.5	34	27
AUG 14			30.0	28.2	8.3	3	3.4	27	20.3	12.8	3.5	1.2	31	26
AUG 21	dull rainy week (Aug 21 – Aug 28)		33.5	32.7	12.9	11.2	12.0	21.5	19.6	13	9.0	2.2	28	29.5
UG 28			26.8	26.0	11.5	9	9.8	21.8	20.5	19.2	14.2	9.5	28.5	28
EPT 5			23.5	21	13	11	10.8	19.7	18.5	14.0	11.2	6.5	22	20
Sept 11	rain, fen much wetter		14.0	14.9	13.9	13.4	12.6	14.0	14.0	13.8	12.5	10	15	15
Sept. 18	dull, choppy, fen still wet		15	14.0	9.8	9.5	9.8	15	14.8	12.4	8.3	7.5	15	15
Sept 25	ref. junc. H_2O frozen on east side		13	7.3	7.0	10	—	4	1.3	3.3	—	6.5	1	2
Oct 3	Super fog.		—	7.6	9.6	10.2	10.3	8.2	8.5	9.5	—	—	8	8
Oct 9	beautiful! [illegible]		9.0	9.1	13	15.6	16.2	3.8	4.0	8.0	3.5	7.8	7	1
Oct 16	overcast		5.1	4.3	6.5	7.0	7.3	2.3	3.5	7.4	—	7.5	2	1
Oct 23	Sunny & cold		-2	0.8	4.1	7.7	7.0	1.0	2.8	6.5	—	8.0	-2	0
Oct 30	Indian summer		5.5	4.0	0.3	1.0	1.0	8.5	0.5	-5.2	-3.5	-1.5	6	7
Nov. 7	sunny, frozen like apple crisp		0.5	-4.5	-2.0	-0.8	-2.8	-1.0	0	2.6	4.0	4.9	1	1
Nov. 14	snow, cold -1 °C		1.2	0.2	1.2	3.1	4.5	0.1	0.2	1.0	2.2	3.2	0	0

Temperatures in Sphagnum hummocks

T_2 = WEST TRANSITION
F_1 = " FEN
M_2 = WEST MUSKEG

ref junction

WEST PLUG F-1, M-2, T-2

T-2 1	2	3	4	5	M-2 6	7	8	9	10	F-1 11	12	13	14	15	T-2 (+1)	M-2 (+1)	F-1 (+0)	DATE 1978
0	-3	-15	-30	-50	0	-3	-15	-30	-50	0	-3	-15	-30	-50				
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				JUNE 7
11.0	11.0	11.0	10.6	7.9	—	—	—	—	12.7	8.5	8.5	8.5	4.9	1.1	10	—	10	8
12.8	13.0	9.0	9.2	7.3	—	—	—	—	—	10.3	9.5	7.5	2.5	2.1	12.5	14.0	14	15
19.0	11.5	13.2	6.2	0.4	17.0	—	—	—	—	21.0	21.0	11.2	8.8	6.2	22.5	18	29	23
27.3	27.8	18.7	16.8	14.0	21.5	20	19.1	16.0	10.0	15.5	13.0	11.0	7.5	3.6	21	20	21.5	30
28.5	28.0	19.5	16.2	14.0	22.4	20.3	18.2	16.0	10.8	19.5	17.0	10.8	7.0	6.0	23	21	24	JULY 10
31.3	30.0	22.5	17.0	14.3	24.7	21.0	18.0	14.5	12.5	23.5	20.8	11.0	7.5	6.0	26	24	27	17
30.2	26.3	20.4	14.3	12.5	26	22.6	14.0	13.6	10.8	26.0	24.5	11.2	9.8	7.9	29	21	26	25
26.0	26.8	21.7	~~22.8~~ 14.5	~~22.8~~ 12.0	25.2	23	8.6	5.3	4.9	28.0	29.0	22.8	22.5	11.3	25	13	30	AUG 1
33.0	31.2	33	14.5	11.7	34	21.8	12.0	7.5	6.2	/	23	11	6.2	7.8	28	19	30	7
32	30	26	15.4	11.7	33.4	25.2	13.5	7.0	7.3	/	19.4	17.5	10.8	9.2	27	23	30	14
28.2	29	21.6	13.2	13.5	29	27.5	20.8	17.5	16.5	/	19	18.5	17	17.5	29	24	23.5	21
25.5	23.5	22.5	15.2	13.9	21	19	14.8	13.3	12.0	/	14	9.2	7.8	7.0	24	18	25.3	28
22.8	21.5	16.3	13.5	13.7	21.2	19.9	16.4	14.5	12.6	/	19.0	11.5	10.0	9.2	19	21	20.5	SEPT 5
14.0	14.0	14.6	13.9	13.5	14.0	14.2	14.0	13.4	13.2	/	13.3	12.8	13.2	13.7	15	14.5	14	11
16.8	11.2	11.8	10.0	10.0	14.4	14.5	12.0	10.4	9.8	/	14.8	9.5	8.5	7.2	15	13.5	15	18
11	8.5	2.2	4.0	7.1	10.0	7.3	3.5	7.0	7.3	/	5.0	4.8	3.6	4.9	12	8.5	8	25
11	10.2	8.5	9.0	9.8	9.8	9.0	8.0	9.2	9.0	/	9.2	8.3	8.8	9.0	9	9	9	OCT 3
← inoperative →					/	/	/	/	/	/	/	/	/	/				9
5.5	4.7	7.0	7.0	7.3	7.2	3.1	4.5	5.5	5.3	/	3.3	4.1	—	6.0				16
bit by a rabbit !!					6.5	2.0	2.8	5.0	6.0	/	1.3	1.4	—	5.2	2.5	3	0	23
14.5	11.1	3	0.1	0.5	13	9.8	0.5	0.2	0.1	/	8	1.2	-0.4	2	13	5	12	30
5.1	-0.08	-3°	-1.8	-0.68	3.6	0.2	-0.2	-1.5	1.5	/	2.7	-0.09	1.0	2.9	3	1.5	1.5	NOV 7
-0.1	-0.3	-0.1	0.1	1.8	3.7	-0.4	-0.3	0.1	1.0	/	0.4	0.1	1.3	3.2	0	0	0	14

Temperatures above Sphagnum hummocks — Aerial Thermocouples

Date 1978		EAST °C MUSKEG M-A RED 10cm	GREEN 25cm	WHITE 50cm	REF	EAST °C TRANSITION T-A. RED 10cm	GREEN 25cm	WHITE 50cm	Re
June 23		22°	24.5	23.8	32°	23.8	18.5	17.9	2
June 30		30	25.2	24.	24°	28	25	21.3	2
July 10		29.3	26.5	24.8	26°	21	26.8	25.8	2
July 17		30.5	28.6	25.8	29°	31	29	28	29
July 25		32	30.0	30.1	30°	29.4	28.1	27.5	27
Aug 1		23.2	26.5	26.9	27.5	30.8	28.6	27.9	22.
Aug 7		34.1	35.5	35.5	33.5	37.8	33.2	30	31
Aug 14		32.2	31.8	31.5	33	33	31	31	30
AUG 21		24.2	26.2	26.9	33	33.7	29	28.5	28
AUG 28		21	23	24.2	26.5	31.0	29.5	27.5	24
Sept 5		22	22	22	23	23.3	22.9	22.9	22
Sept 11	RAINY DAY	14.5	14.2	14.2	15	14.5	14.2	14.2	15
Sept 18		17.5	16	11.7	17.5	15.5	16.5	16.5	17
Sept 25		5.8	7.5	9.0	5°	11.5	16.3	15.8	5
Oct 3		9.0	8.5	8.5	9	11.0	9.2	9.2	9
Oct 9	FA, taken 1½ hrs after MA + TA	2.2	3.2	4	1	3.6	5	4	0
Oct 16	cloudy, readings not taken	—	—	—	—	—	—	—	—
Oct 23	Sunny day, but cold	-3.5	-3	2.9	-4	8	2	0.3	-2
Oct 30	Indian summer	13	16	17	12°	18.4	18.4	16.7	14
NOV. 7	Sunny, frozen like apple crisp.	4.0	9.0	11.5	1.5	10	13.1	12.5	2
NOV. 14	cold + grey	1.0	-1.8	-1.4	0	0.8	-0.3	-0.8	0

Temperatures above Sphagnum hummocks

Aerial Thermocouples continued

°C

Fen F-A

Date 1978		RED 10cm	GREEN 25cm	WHITE 50cm	Ref
June 23		25.1	24	23.2	34
June 30		25.2	25.2	24.5	21.5
July 10		28.0	26.2	25.0	24
July 17		32.5	27.0	25.8	27
July 25		35.5	38.0	33.8	31°
Aug 1		34.3	29.1	30.2	31°
Aug 7		32.2	31.9	28.2	29
Aug 14		34	31	30	28
AUG 21		38	35.3	33	30°
AUG 28		30.8	30.2	28.5	27
Sept 5		27.6	27.0	25.5	23
Sept 11	RAINY DAY	14.2	14.5	14.9	15
Sept 18		7.9	10.8	11.0	17
Sept 25		6.6	14.2	14.2	18
Oct 3		12.8	12.2	11.8	11
Oct 9	FA, taken 1½ hrs after MA + TA	13.5	17.2	15.2	12°
Oct 16	cloudy, readings not taken				
Oct 23	Sunny day, but cold	6.5	10.0	8.7	4
Oct 30	Indian summer.	18.8	21.5	20.5	12
Nov 7	Sunny, frozen like apple crisp.	14.1	13.5	13.5	6
Nov 14	cold & grey	-0.4	-0.8	-1.0	0

William Bog

Snow conditions and weather

ate	Comments	LOCATION - Depth cm 1	2	3	4	5	6	7	8
ec 12/77	sticky, deep snow, warm					13	15	11	15
ec 28/77	crusted, strong NW wind, cold clear					8	10	7	10
n 8/78	powder, crust beneath, strong NW wind, cold clear	30	20	13	7	17	20	14	25
n 15/78	, powder, clear in am, clouded in pm, not cold	30	20	13	7	17	20	14	25
n 30/78	drifted & blown, scoured in fen, hard packed in transition, fluffy in muskeg, clear, not cold	28	16	15	13	14	13	10	22
eb 13/78	warm clear, west side melted on S. side of b.S hollows, e side solid	27	18	15	13.5	16	23	14.5	23
rch 7/78	sticky snow, blown, −5°c clear	23	17.5	14	13	13.5	33	13	20
rch 20/78	overcast, heavy snow, strong E wind	36	28.5	32	24.5	35	52	11	38
rch 27/78	overcast, sticky snow +2°c, Topsot hummocks exposed	21	15	14.5	10	22	38	9	26.5
ril 2/78	icysnow dunes run E-W in fen, W side wet, strong E wind −2°c, overcast	11	19	23	10	12	27	15	21.5
pril 20/78	all melted except M, fen frozen solid 12°c clear, strong E wind.	5	0	0	0	0	0	0	19.5

Appendix III

Water/ Soils data

JUNE 1978 - William Bog

water pH (JUNE 1978)

EAST

Quadrat	pH
A-10	4.80
9	4.80
8	5.00
7	5.15
6	5.00
5	4.90
4	5.15
3	5.25
2	4.90
1	5.30
11	4.80
12	4.90
13	5.20
14	5.40
15	5.60

EAST

	pH
B-16	4.70
17	4.78
18	4.75
19	4.88
20	4.88
21	4.90
22	4.65
23	4.70
24	4.73
25	4.75
26	4.90
27	5.80
28	5.63
29	5.70
30	5.88

NORTH

	pH
C-31	6.70
32	6.70
33	6.70
34	6.42
35	6.51
36	6.49
37	6.60
38	6.20
39	6.05
40	5.75
41	5.88
42	5.65
43	5.82
44	5.90
45	5.98
46	5.95

NORTH

	pH
D-47	6.81
48	6.70
49	6.65
50	6.70
51	6.62
52	6.62
53	6.65
54	6.65
55	6.65
56	6.60
57	6.75
58	6.60
59	6.75
60	6.80
61	6.50

WEST

	pH
E 62	6.20
63	6.30
64	6.30
65	5.82
66	6.45
67	6.65
68	6.60
69	6.55
70	7.00
71	6.80
72	6.75
73	6.78
74	6.72
75	6.50

WEST

	pH
F 76	6.90
77	5.95
78	6.25
79	6.30
80	6.68
81	6.95
82	6.88
83	7.05
84	7.05
85	7.10
86	7.08
87	6.90
88	6.62
89	6.58

EAST

	pH
G-90	5.58
91	5.45
92	5.52
93	5.55
94	5.65
95	5.60
96	5.58
97	5.30
98	5.28
99	5.30
100	5.18

- NOVEMBER 1978 - William Bog

MOIST PEAT pH

EAST	pH
A1 muck	4.95
A2 musk	4.65
A3 musk	4.82
A4 musk	4.25
A5 musk	4.51
A6 trans	4.70
A7 dry trans	4.80
A8 dry trans	4.71
A9 dry trans	4.50
A10 trans	5.0
A11 hummocky fen	5.15
A12 hummocky fen	5.02
A13 fen	5.25
A14 fen	6.20
A15 fen	5.85

NORTH	pH
C1 musk hum top	4.15
C2 musk	6.15
C3 musk	6.52
C4 musk.	6.25
C5 dry trans.	6.42
C6 dry trans.	6.48
C7 wet trans.	6.58
C8 wet trans.	6.50
C9 Phrag. fen	6.25
C10 hum. fen	6.75
C11 hum. fen	7.15
C12 hum fen	6.55
C13 hum fen	7.05
C14 hum fen	7.22
C15 fen	6.45

NORTH	pH
D1 dry musk	7.20
D2 dry musk	6.00
D3 brd leaf sedge musk	6.82
D4 MUSK	7.10
D5 musk edge	7.40
D6 dry trans	7.45
D7 dry trans	6.65
D8 dry trans	6.82
D9 wet trans.	6.60
D10 fen	6.70
D11 fen	6.20
D12 fen	6.39
D13 hum fen	6.50
D14 fen	6.35
D15 fen	5.75

WEST	pH
E1 MUSK	5.98
E2 MUSK	5.85
E3 MUSK	5.50
E4 MUSK	5.85
E5 MUSK Edge	6.68
E6 tran	6.25
E7 trans	6.05
E8 trans	7.25
E9 trans	6.75
E10 trans	5.82
E11 trans	5.80
E12 humm fen	6.20
E13 hum fen	6.65
E14 hum fen (hum top)	3.78
E15 hum fen	7.35

NORTH	pH
F1 cedar musk	6.05
F2 musk	6.65
F3 musk	6.25
F4 MUSK.	6.35
F5 MUSK	6.15
F6 MUSKEDGE	5.80
F7 dry trans	6.00
F8 trans	5.85
F9 trans	6.08
F10 trans	6.18
F11 hum fen	6.60
F12 hum fen	6.85
F13	
F14 fen	6.68
F15 fen	6.32

JUNE 1978 - William Brg 312.

von Post humification of peat

A-1 → quadrat
- 4 → value

DRAT | EAST — NORTH — WEST

A.

	10 - 4
	9 - 4
EG	8 - 3
	7 - 4
	6 - 3
	5 - 1
	4 - 4
	3 - 4
S	2 - 1
	1 - 1
	11 - 3
	12 - 5
	13 - 5
	14 - ~~8~~ 3
	15 - 5

B.

	16 - 3
	17 - 2
MUSKEG	18 - 3
	19 - 3
	20 - 2
	21 - 2
	22 - 2
	23 - 3
TRAN	24 - 4
	25 - 2
	26 - 4
	27 - 4
FEN	28 - 3
	29 - 4
	30 - 2

C.

	31 - 4
	32 - 4
MUSKEG	33 - 5
	34 - 4
	35 - 3
	36 - 4
	37 - 5
	38 - 4
TRANSITION	39 - 5
	40 - 4
	41 - 4
	42 - 3
	43 - 3
	44 - 4
FEN	45 - 3
	46 - 5

D.

	47 - 3
	48 - 2
MUSKEG	49 - 2
	50 - 3
	51 - 5
	52 - 4
	53 - 4
	54 - 4
TRAN	55 - 3
	56 - 4
	57 - 5
	58 - 4
FEN	59 - 4
	60 - 4
	61 - ~~4~~ 5

E.

	62 - 4
	63 - 5
MUSKEG	64 - 5
	65 - 5
	66 - 4
	67 - 2
TRAN.	68 - 3
	69 - 4
	70 - 4
FEN	71 - 5
	72 - 3
	73 - 2
	74 - 4
	75 - 4

WEST

F.

	76 - 3
	77 - 1
MUSKEG	78 - 3
	79 - 3
	80 - 4
	81 - 4
TRNS	82 - 5
	83 - 5
	84 - 5
	85 - 4
	86 - 4
FEN	87 - 4
	88 - 7
	89 - 7

EAST

G.

	90 - 4
	91 - 3
	92 - 4
	93 - 3
Transition	94 - 3
	95 - 5
	96 - 5
	97 - 3
	98 - 3
	99 - 3
	100 - 1

JUNE 1978 - William Bog
% Loss on ignition of peat

QUADRAT | EAST

Zone	A	Zone	B
	A - 10 - 83.47 %		B 16 - 80.23 %
	9 - 86.25		17 - 81.91
EG	8 - 91.49	MUSKEG	18 - 87.47
	7 - 82.64		19 - 91.66
	6 - 89.17		20 - 88.34
	5 - 92.38		21 - 90.38
	4 - 88.10		22 - 85.55
	3 - 83.33		23 - 78.10
AS	2 - 88.99	TRAN	24 - 81.59
	1 - 86.51		25 - 89.47
	11 - 90.03		26 - 72.88
	12 - 83.14		27 - 83.25
	13 - 71.15	FEN	28 - 8[illegible].30
	14 - 89.88		29 - 79.60
	15 - 65.51		30 - 82.14

NORTH

Zone	C	Zone	D
	C. 31 - 84.20 %		D. 47 - 80.73
	32 - 62.95		48 - 91.77
MUSKEG	33 - 79.41	MUSKEG	49 - 77.00
	34 - 80.78		50 - 69.57
	35 - 78.60		51 - 84.48
	36 - 68.86		52 - 93.10
	37 - 76.83		53 - 80.49
	38 - 70.06		54 - 75.76
TRANSITION	39 - 80.28	TRANS	55 - 80.67
	40 - 52.28		56 - 84.03
	41 - 71.94		57 - 59.05
	42 - 75.46		58 - 80.81
	43 - 84.32	FEN	59 - 74.63
	44 - 80.77		60 - 74.11
FEN	45 - 80.85		61 - 81.72
	46 - 63.88		

WEST

Zone	E
	E. 62 - 80.30 %
	63 - 79.46
MUSKEG	64 - 44.13
	65 - 79.56
	66 - 77.78
	67 - 80.41
TRAN.	68 - 78.74
	69 - 58.23
	70 - 73.28
FEN.	71 - 62.27
	72 - 73.56
	73 - 42.41
	74 - 72.42
	75 - 70.45

WEST

Zone	F
	F-76 - 80.14 %
	77 - 88.89
MUSKEG	78 - 72.29
	79 - 75.63
	80 - 78.27
	81 - 55.94
TRANS	82 - 53.37
	83 - 70.35
	84 - 57.81
	85 - 63.62
	86 - 63.19
FEN	87 - 63.73
	88 - 55.54
	89 - 73.26

EAST

Zone	G
	G - 90 - 71.76 %
	91 - 77.22
	92 - 76.19
	93 - 80.49
TRANSITION	94 - 76.58
	95 - 74.62
	96 - 78.40
	97 - 76.92
	98 - 70.05
	99 - 79.93
	100 - 84.89

*(TRANSECTS A and F only) JUNE 1978 - William Bog

Available nitrogen ppm. in peat

EAST

Zone	Quadrat	NH_4^+ ppm	NO_3^- ppm
	A-10	84	1.0
	9	88	1.0
(Musk)eg	8	120	1.0
	7	204	1.0
	6	104	32.0
	5	135	1.0
	4	72	1.0
	3	115	4.0
(Tra)ns	2	87	1.0
	1	84	1.0
	11	105	1.0
	12	102	1.0
	13	98	1.0
	14	168	6.0
	15	126	1.0

*B. 16, 17, 18 (MUSKEG), 19, 20, 21, 22, 23, 24 (TRAN), 25, 26, 27, 28 (FEN), 29, 30

NORTH

*C. 31, 32, 33 (MUSKEG), 34, 35, 36, 37, 38, 39 (TRANSITION), 40, 41, 42, 43, 44, 45 (FEN), 46

*D. 47, 48, 49 (MUSKEG), 50, 51, 52, 53, 54, 55 (TRANS), 56, 57, 58, 59 (FEN), 60, 61

WEST

*E 62, 63, 64 (MUSKEG), 65, 66, 67, 68 (TRAN.), 69, 70, 71 (FEN.), 72, 73, 74, 75

WEST

Zone	Quadrat	NH_4^+	NO_3^-
	F-76	94	1.0
	77	50	1.0
Muskeg	78	174	12.0
	79	100	3.0
	80	70	4.0
	81	62	1.0
Trans.	82	84	1.0
	83	58	4.0
	84	58	18.0
	85	40	3.0
	86	68	5.6
Fen.	87	82	1.0
	88	134	5.0
	89	128	4.0

EAST

*G-90, 91, 92, 93, 94 (Transition), 95, 96, 97, 98, 99, 100