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Phase II - Peat Program Forestry - Plant Communities Report

Vegetation Types, Species and Areas of Concern and Forest Resources Utilization of Northern Minnesota's Peatlands

Prepared for the

Minnesota Department of Natural Resources

by

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Introduction

This report summarizes the results of studies conducted pursuant to a research contract by the College of Forestry, University of Minnesota, with the Minnesota Department of Natural Resources entitled Phase II - Peat Program Forestry - Plant Communities.

Objectives of this study as prescribed were as follows:

1. Survey and assessment of previous studies on peatland vegetation types and plant community associations.

2. Identification and verification of potential resources conflicts associated with peat development; i.e. natural areas, forest products and unique plants.

3. Recommendation of future investigations and information acquisition for further refinement of guidelines for peat development.

The project format involved an assessment and evaluation of published literature and other information sources relevant to northern Minnesota's peat, vegetation and potential resource conflicts associated with possible peatland development.

The study area considered was primarily, but not exclusively, Roseau, Beltrami, Lake of the Woods, Koochiching, Itasca, Aitkin, Carlton, and St. Louis counties.

Principal emphasis in the study includes plant communities and their relationship to environmental conditions and processes; individual plant species and areas of special concern; and the peatland forest resource and its current industrial utilization.

PHYSIOGNOMIC CLASSIFICATION OF PEATLANDS

The development of diverse vegetation types in different areas of a peatland is related to the flow, level, and chemistry of groundwater. Levels of nutrient ions, oxygen content, and pH of the water supply are key factors (Heinselman, 1963b; 1970).

Water chemistry tends to vary along a gradient. Highest concentrations of nutrients are along peatland margins near mineral soil. The concentration decreases towards central bog areas with thick peat accumulations (central raised bogs). Abrupt changes in groundwater chemistry tend to be reflected by markedly different vegetation types on the surface. A gradual gradient results in gradual changes in vegetation types. The effect of these variables is that certain plant communities are clearly identifiable, while others can only be divided somewhat arbitrarily along a vegetation continuum.

Water chemistry can be related to source. Groundwater flowing into a peatland from adjacent areas of mineral soil (minerotrophic) has a different makeup than peatland waters which have originated from direct rainfall and have not flowed through mineral soil (ombrotrophic). The degree of ombrotrophy or minerotrophy of peatland waters correlates well with the vegetation of the area (Sjors, 1959; Heinselman, 1963b; 1970).

Peatlands can be divided into three main physisiognomic classes: bogs, fens, and swamps. A fourth class, marsh, by definition does not accumulate significant amounts of peat (Jeglum et al., 1974). The classes are defined by plant cover, water chemistry, and peat type.

Bog

Bogs are peat-covered or filled areas with a high water table and a surface carpet of mosses, chiefly sphagnum. The surface is often raised; or if it is flat or level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Precipitation is the major source of water and nurtients for the bog surface. Surface bog waters and peat are usually strongly acid and extremely deficient in mineral nutrients. Sphagnum species are responsible for the acidic reaction. Oxygen saturation is low. Upper peats are usually mainly sphagnum remains, are acidic, and undecomposed (Jeglum et al., 1974). Sedges may be present on bogs. If a tree layer is present, it consists mainly of black spruce (*Picea mariana*) or tamarack (*Larix larcinia*). Ericaceous species typify the bog shrub layer. Common shrub species are leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glaucophylla*), bog laurel (*Kalmia polifolia*), and cranberries (*Vaccinium* spp.).

Fen

Fens are peatlands with surface layers of poorly to moderately decomposed sedge peat. Basal peats are often well decomposed. Sedges are the dominant vegetation, often in association with grasses and reeds. Sphagnum is subordinate or absent. A low to medium height shrub layer may be present. Trees are usually restricted to raised strings or islands (Heinselman, 1970). The water and peat in fens are less acidic than those of bogs. Typically, slow drainage occurs through seepage down low gradient

slopes (Jeglum et al., 1974). As a result of the slow drainage oxygen saturation is low and the mineral nutrient supply is restrictive.

Swamp

Swamps are defined as wooded wetlands where standing or gently flowing surface water persists for long periods. While most swamps are dominated by trees some are dominated by shrub thickets. The substrate is usually waterlogged. The water is circumneutral to mildly acidic with little or no deficiency in oxygen or mineral nutrients. The substrate is a mixture of mineral and organic sediment or peat (Jeglum et al., 1974). Swamps are typically the most minerotrophic peatland type. They are also floristically richer than either bogs or fens and may be productive forests.

The groundwater characteristics of bogs, fens, and swamps are compared in Table 1. Indicator species for each of the water conditions described in Table 1 are listed in Table 2.

Table 1. Groundwater Characteristics of Bog, Fen, and Swamp.

Bog: (ombrotrophic)

pH range: 3.1 - 4.2
Ca content: 0.8 - 2.7 ppm
Ca + Mg content: 1.0 - 3.0 ppm
"corrected conductivity": ≈ 0

Fen or Poor Swamp: (weak minerotrophic)

pH range: 4.3 - 5.8
Ca content: 3 - 10 ppm
Ca + Mg content: 5 - 13 ppm
"corrected conductivity": 20 - 75 µMhos

Swamp: (minerotrophic)

pH range: 5.8 - 7.0
Ca content: 10 - 25 ppm
Ca + Mg content: 13 - 30 ppm
"corrected conductivity": 75 - 120 µMhos

Source: Heinselman, 1970.

Table 2. Indicator Species of Bog, Fen, and Swamp Waters.

Species of Bog Areas (ombrotrophic)

Picea mariana
Kalmia polifolia
Chamaedaphne calyculata
Eriophorum spp.
Pleurozium schreberi
Sphagnum fuscum

Species of "poor swamp" or Fen Areas (weak minerotrophic)

Larix laricina
Betula pumila
Andromeda glaucophylla
Menyanthes trifoliata
Iris versicolor
Utricularia spp.
Typha latifolia
Phragmites communis
Carex lasiocarpa

Species of "rich" swamp areas (minerotrophic)

Thuja occidentalis
Fraxinus nigra
Betula papyrifera
Abies balsamea
Alnus rugosa
Cornus stolonifera
Rubus strigosus
Cornus canadensis
Dryopteris cristata
Maianthemum canadense
Trientalis borealis
Rubus pubescens
Impatiens biflora
Coptis trifolia
Mitella nuda
Galium aparine
Galium trifolorum
Caltha palustris
Clintonia borealis
Linnaea borealis
Calamagrostis canadensis

Source: Heinselman, 1970.

WETLAND VEGETATIONAL PROCESSES

Minnesota's peatlands are the result of two wetland vegetational processes; hydrarch succession and paludification. Hydrarch succession is the classic lake-filling sequence as described by Transeau (1903), Cooper (1913), Dachnowski (1924), and others. This process is active in the development of smaller bogs in wet depressions in moraine areas, outwash plains, and on the Laurentian Shield. The succession is perceived as proceeding from an initial aquatic vegetation stage towards a more mesophytic climax, with several wetland stages and continuous peat deposition occupying the interim. The hydrarch succession occurs within the limits of the wet depression, and adjacent uplands are not subject to hydrarch processes.

Paludification, in contrast, is a process of wetland expansion. The wetland may actually move up gentle slopes into upland communities, greatly modifying vegetation. This process was only recently recognized in Minnesota. Heinselman (1963b) discussed evidence for paludification as an important process in Minnesota's Lake Agassiz area.

Hydrarch Succession

The successional stages of a filled lake bog may be described by four or five major plant community types (aquatic → pioneer mat → moss heath → bog forest → upland climax). On a bog intermediate in the succession, the stages are visible in sequence from the bog center to the edge. Variations in environmental factors may suppress one stage or favor another. The

general sequence, however, is fairly consistent (Conway, 1949; Gates, 1942; Joyal, 1971; Cooper, 1913). Different authors have found variations in the actual plant associations to be found at each stage, and the concept of succession to climax forest is treated differently. Hydrarch stages as described by Cooper (1913) on Isle Royale, Conway (1949) in central Minnesota, and Gates (1942) in northern lower Michigan are compared (Table 3).

The first vegetation in a pond or lake is, of course, aquatic. The pioneer mat is the first community type to establish itself above the water's surface. An association dominated by the sedge *Carex lasiocarpa* is the most common mat-former. Other sedges may be present or the pioneer community may be dominated by nonsedge plants such as cattail (*Typha latifolia*) or water-willow (*Decodon verticillatus*). The pioneer mat will occupy the margin about the remaining open water of the shrinking lake or pond. The next community type is the moss-heath or moss-shrub type. The typical association is dominated by leatherleaf with sphagnum moss ground cover. Other heath species are commonly present, including bog rosemary and cranberries or blueberries (*Vaccinium spp.*). A transitional association may precede the moss-heath in its invasion of the pioneer mat. The transition is characterized by invading *Sphagnum subsecundum* or *Sphagnum recurvum*, and cranberries (*Vaccinium macrocarpon* or *oxycoccos*).

The moss-heath may be followed by a high bog shrub community (Gates, 1942) or may be invaded directly by the bog forest (Conway, 1949). The moss-heath may develop a high shrub component in its mature stages. This

Table 3. Hydrarch Succession of Plant Communities as Described by Three Authors.

	Central Minnesota (Conway, 1949)	Northern Lower Michigan (Gates, 1942)	Isle Royale (Cooper, 1913)	
Lake Aquatics	*Carex lasiocarpa*	*Menyanthes trifoliata* *Sagittaria latifolia* *Carex lasiocarpa*	*Menyanthes trifoliata*	
Pioneer Mat	*Typha latifolia* *Decodon verticillatus* *Carex prairea*		*Carex limosa*	*Carex lasiocarpa* (or) *Scirpus cespitosus*
Mat-Heath Transition	*Vaccinium macrocarpon* *Sphagnum subsecundum* *Andromeda glaucophylla* *Aulacomnium palustre*		*Sphagnum** invasion	no *Sphagnum**
Moss-Heath	*Chamaedaphne calyculata* *Sphagnum recurvum* *Sphagnum magellanicum*	*Chamaedaphne calyculata* *Sphagnum sp.*	*Sphagnum spp.* *Chamaedaphne* *Andromeda*	
High bog Shrub	*Betula pumila*	*Nemopanthus mucronata* *Alnus rugosa* *Betula pumila* *Salix pedicellaris* *Aronia spp.*	*Ledum-Sphagnum*	*Chamaedaphne* *Andromeda* *Alnus incana*[1/]
Bog Forest Invasion	*Larix laricina*	*Larix laricina*	*Larix*	*Larix*
Bog Forest Dominant	*Picea mariana* *Thuja occidentalis*	*Picea mariana* *Thuja occidentalis*	*Picea mariana*	*Thuja occidentalis*
Climax Dominant	*Picea mariana** *Abies balsamea*	*Thuja occidentalis*	*Abies, Betula* *Picea canadensis*	*Abies, Betula* *Picea canadensis*[2/]

* Not considered distinct

[1/] *Alnus incana* = *Alnus rugosa* (Du Roi) Spreng

[2/] *Picea canadensis* = *Picea glauca* (Moench) Voss

is likely to be bog birch (*Betula pumila*) and willow (*Salix pedicellaris* or other *Salix spp.*). Alder (*Alnus sp.*) may be present if nutrients are sufficient and pH is not too low.

The pioneer tree species to invade the moss-heath or high bog shrub is almost always tamarack. Tamarack establishes a zone of dominance, and in turn is invaded by black spruce or northern white-cedar (*Thuja occidentalis*). Eventually, tamarack reproduction is shaded out and the bog forest dominant is either *Picea* or *Thuja*.

It is unclear what the nature of the ultimate climax of this succession is, or even if the concept of a mesophytic climax should apply to bogs. Gates (1942) sees an association dominated by northern white-cedar as the eventual climax for boggy areas in lower Michigan (Table 3). He predicts the ultimate elimination of the bog altogether by upland vegetation. Conway (1949) finds black spruce to be the most common bog forest dominant, with northern white-cedar dominant in a few areas, and some situations of codominance. The upland climax of this area (central Minnesota) is the maple-basswood forest. It is considered to be unlikely that maple-basswood will occupy the bog sites, and instead, the possibility of a balsam fir (*Abies balsamea*) dominated coniferous climax is suggested as the eventual climax for bog sites. Cooper (1913) on Isle Royale sees all successional processes as leading to a balsam fir, paper birch (*Betula papyrifera*) and white spruce (*Picea glauca*) dominanted climax (Table 3).

A community type which is directly the result of environmental influences rather than successional direction is sometimes found at the edge of the filled-lake depression (Cooper, 1913; Conway, 1949). This marginal

fen is variable in its plant associations, but often has an abundance of speckled alder (*Alnus rugosa*) and basiphilous sedges such as *Carex riparia* and *Carex stricta*. Well developed marginal fens may have a tree component of black ash (*Fraxinus nigra*) (Conway, 1949).

The marginal fen is the result of the influence of waters draining from the adjacent uplands into the bog. Near neutral in pH and relatively well-supplied with nutrients, the upland waters produce a zone of greater minerotrophy, and modify acidic bog water in the immediate area to a more neutral pH (Conway, 1949).

The typical sequence of peat layers formed by the hydrarch succession begins with aquatic peat in contact with mineral soil. Aquatic peat is overlaid by reed-sedge peats deposited by the sedge mat stages. The reed-sedge layer grades into peats with greater moss and wood content towards the surface (forest peats). Surface vegetation is typically a bog forest.

Paludification

Paludification processes and development of sphagnum dominance in the large peatlands of the Lake Agassiz area have built a different peat sequence. Heinselman (1970) mapped peat stratigraphy in the Myrtle Lake region in eastern Koochiching County. Small depressions in the underlaying lake bed show aquatic peat, topped by reed-sedge peat. This is typical of a beginning hydrarch succession. However, more sampling points showed that the sedge fens centered on these smaller depressions expanded outwards. The gentle terrain, impermeable nature of the lacustrine soil, and drainage patterns allowed radial fen expansion. Deposition of sedge

peats slowed surface water flow and created wet areas just upslope of the advancing sedge fen. In this way the fen increased in area.

The expansion of sedge fen is linked to a period of warm, dry climate beginning about 8000 years ago. About 5000 years ago, development of a cooler and wetter climate allowed invasion of the fen by bog conifers. Swamp forests expanded upslope from the fen areas, building basal forest peats in areas roughly centered on the fens.

This process was revealed by the concentric nature of the basal peat types which underlay the peatland today (Heinselman, 1963b; 1970). Expansion by paludification, first by sedge fen and later by swamp forest, has been the process responsible for the large size of the Myrtle Lake peatland. A similar course of development probably occurred in the other large peatlands in the Agassiz basin.

The swamp forests were, in turn, modified and displaced in areas by sphagnum moss. Invasion by sphagnum in turn led to the development of raised bogs. Accumulations of sphagnum peat has been accompanied by rising water tables and timber site deterioration (Heinselman, 1963b).

Raised bog development at Myrtle Lake was initiated by two events. Progressive climate change had increased moisture sufficiently to favor sphagnum growth; and headwater erosion by a local stream changed water flow patterns, developing a water table divide in the northern part of the peatland. This reduced the flow of mineralized water from adjacent uplands into the divide area, shifting groundwater chemistry towards dependence on rainfall--ombrotrophy. The decreased nutrient levels of ombrotrophic waters

selectively favor sphagnum mosses. The invading sphagnum flourished, and raised bog development began (Heinselman, 1970).

Sphagnum invasion at Myrtle Lake began about 2700 years ago. The oldest sphagnum peats of other raised bogs of the Agassiz basin date from 2000 to 2500 years old (Heinselman, 1963b).

VEGETATION TYPES

A wetland classification system was devised by Jeglum et al. (1974) for a large peatland region of southern Ontario. Fox et al. (1977) modified the Jeglum system, defining physiognomic classes and associated dominant vegetation more recognizable from aerial photographs of the Lake Agassiz region of Minnesota. Various authors writing on peatland vegetation, describe plant communities on the basis of floristics. These community types can be fit within the coarser units of the Fox-Jeglum system. This system with some modifications in terminology, has been adopted as a framework for this report.

Peatland vegetation studies indicate that moisture and nutrient regimes are the two main factors controlling species distribution and vegetational patterns (Jeglum, 1971). Thus, plant communities can often be used to indicate moisture and nutrient regimes of the peatland environment.

The method of synecological coordinates (Bakuzis, 1959; 1967) was used to show the distribution and interrelationships of vegetation types on moisture and nutrient axes (Fig. 1). This method is based on the premise that moisture, nutrient, heat, and light regimes to which each plant in a community responds are measured indirectly by the presence of the plants. The community synecological coordinates are simple averages of all species coordinates present in the community. Each dot in Figure 1 marks a coordinate position representing relative levels of peatland moisture and nutrients for a given community. The community coordinates were computed from plant sites of lowland studies by Bakuzis, 1959; Heinselman, 1970; Hansen et al.,

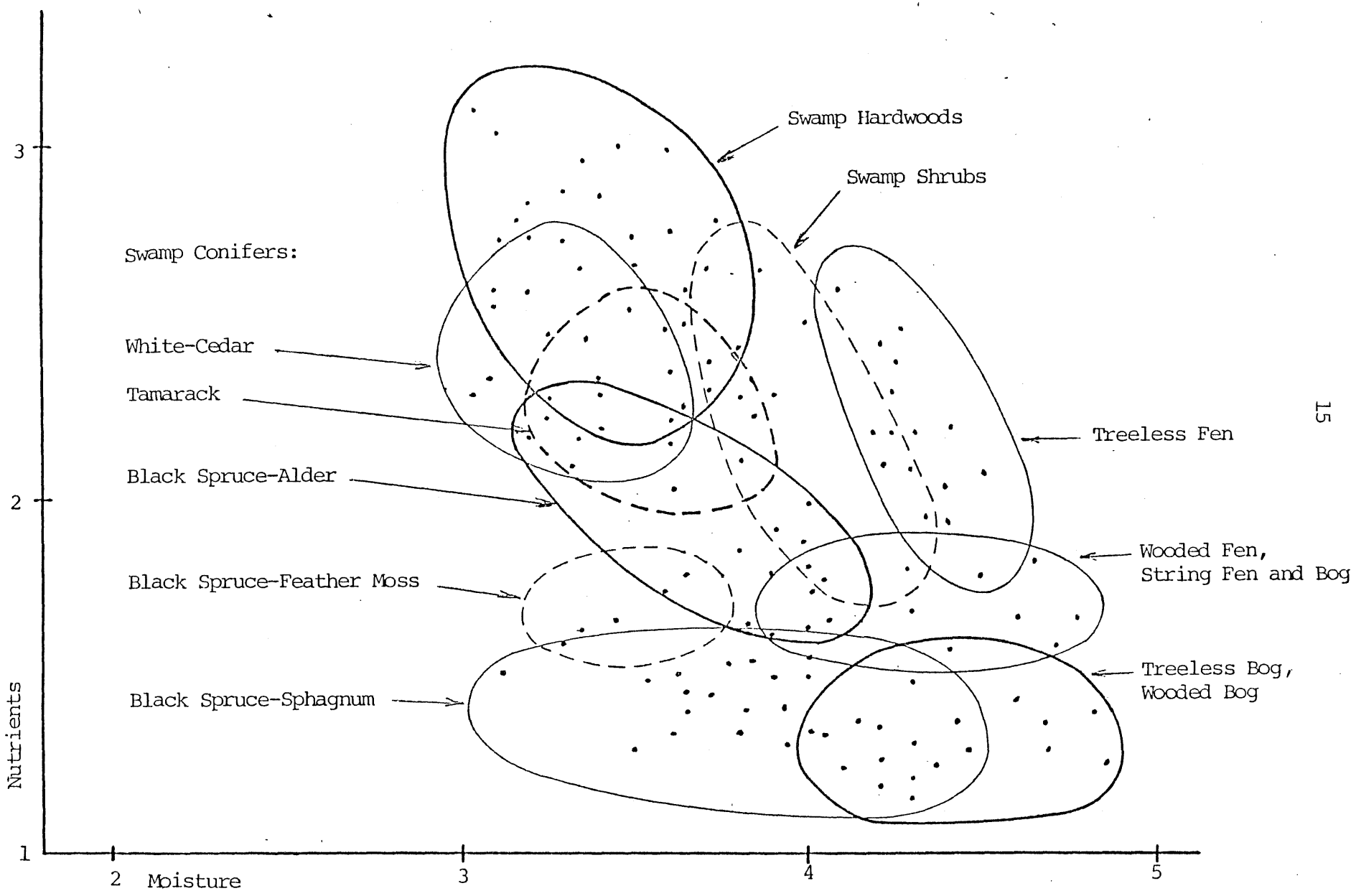

Figure 1 - Edaphic Relationships of Lowland Vegetation Types in Northern Minnesota.

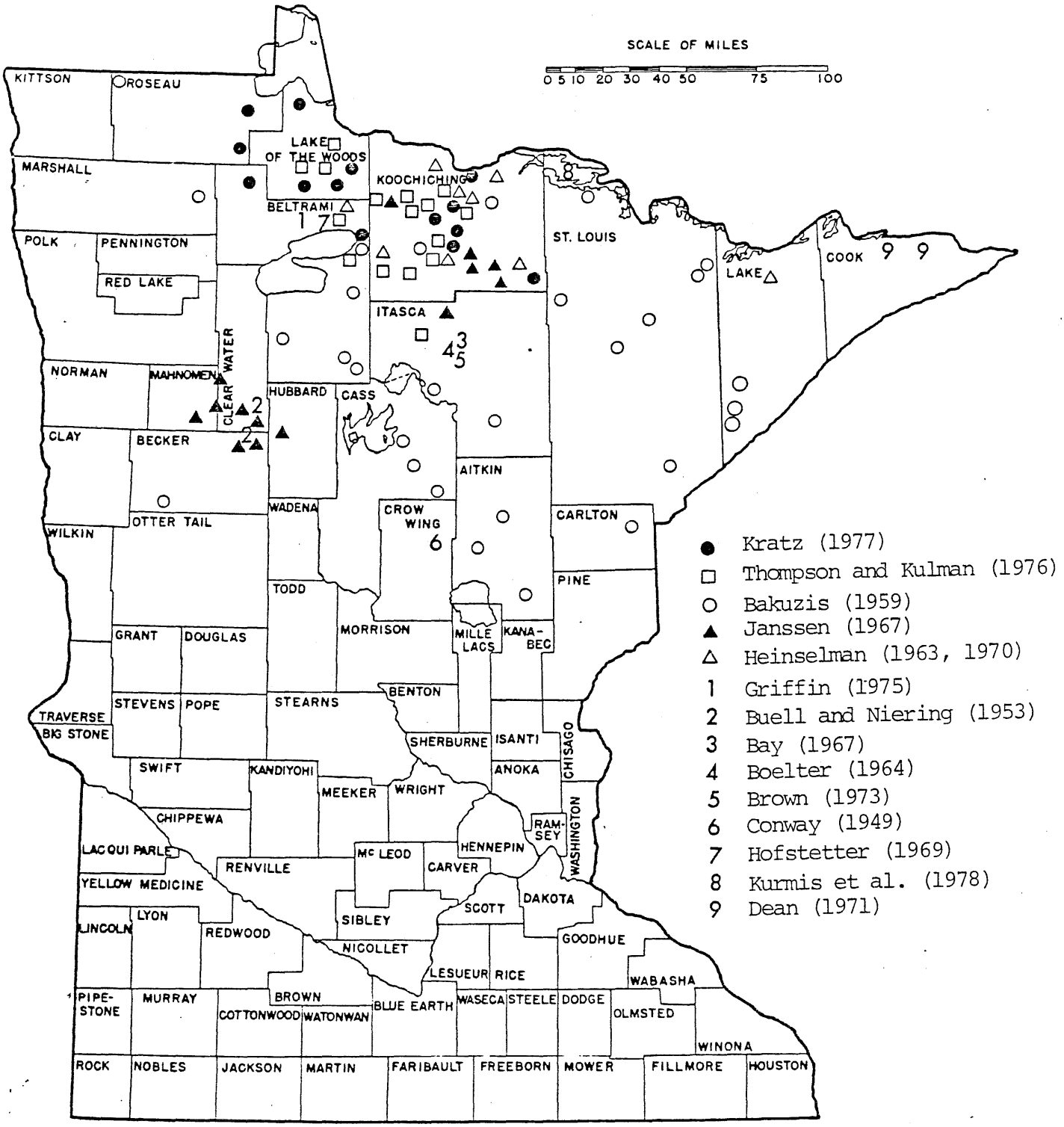

Figure 2. Locations of Peatland Vegetation Studies in Northern Minnesota.

1973; Kratz, 1977; and Kurmis et al., 1978. Locations of these study areas and others are shown in Figure 2. The vegetation types were delineated based on the criteria outlined by Fox et al., 1977 and Jeglum et al., 1974. There is a considerable overlap of vegetation types in the edaphic field (Fig. 1) because these vegetation types are based largely on dominant plant cover while the plant community locations in the edpahic field are based on all plants present in the community. Furthermore, only moisutre and nutrient axes are considered here. If light and heat coordinates were used, further separation would be possible. Figure 1 illustrates the range of moisture and nutrient intensity levels of each vegetation type and how each vegetation type relates to others.

Treeless Bog

Treeless (open) bogs are dominated by sphagnum heath, usually on lower slopes of raised bogs. Heinselman (1970) describes the terrain as wet and soggy with a cover of large "pillows" of *Sphagnum fuscum*, which is essentially continuous. The peat layer is 10-25 feet thick. A half shrub layer of *Chamaedaphne*, *Kalmia*, and *Vaccinium oxycoccos* is typical. The only trees are black spruce and an occasional tamarack covering up to five percent of the area. Heinselman (1970) calls this vegetation type Sphagnum-leatherleaf-Kalmia-spruce heath and a plant list from the Myrtle Lake peatland study area in Koochiching County, characterizing this vegetation type follows:

Trees

Picea mariana
Larix laricina

Half Shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Kalmia polifolia
Ledum groenlandicum
Vaccinium oxycoccos
Vaccinium vitis-idaea var. *minus*

Forbs

Sarracenia purpurea
Smilacina trifolia

Grasses, Sedges

Carex spp.
Eriophorum spp.

Mosses, Lichens

Cladonia spp.
Pleurozium spp.
Sphagnum magellanicum
Sphagnum spp.

Wooded Bog

This vegetation type is an open, stunted black spruce forest (muskeg) very common on sphagnum peatlands in northern Minnesota and Canada. Fox et al. (1977) defines muskeg as having 5 to 25 percent tree cover. Black spruce dominates with an occasional tamarack. The poorest sites are open, and 100-year old spruce may be less than 20 feet tall (Heinselman, 1963b; 1970; Kratz, 1977). Denser stands are found in topographically oriented groves on crests and upper slopes of raised bogs. Sphagnum hummocks have *S. fuscum* or *S. capillaceum* and *S. magellanicum* or *S. palustre* and *S. recurvum* occupying hollows. Feather mosses appear in stands that are dense enough. The sphagnum hummocks are covered with a heavy low shrub layer of *Chamaedaphne*, *Kalmia*, *Ledum*, and *Andromeda*. Heinselman (1970) indicates that this type (Sphagnum-black spruce-leatherleaf) merges gradually with Sphagnum-leather-leaf-Kalmia-spruce heath (treeless bog) along slopes of raised bogs. Transitions to poor swamp forest (wooded fen) are usually abrupt. Wooded bog also merges gradually with black spruce-feather moss type or may become

what Fox et al. (1977) calls spruce-raised bog type, a mixture of swamp spruce and muskeg types or a black spruce-sphagnum forest with tree cover over 25 percent. A plant list of the wooded bog community, *Piceto-Chamaedaphnetum*, as described by Janssen (1967) in Koochiching County, follows:

Trees

Picea mariana

Half shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Kalmia polifolia
Ledum groenlandicum
Oxycoccus quadripetalus

Forbs

Sarracenia purpurea
Smilacina trifolia

Grasses, Sedges

Eriophorum gracile

Mosses, Lichens

Sphagnum spp.

Treeless Fen

Treeless (open) fen is characterized by a dense layer of graminoids. Sedges are the usual dominants, but grasses are common. Forbs are sometimes conspicuously associated with graminoids. The mosses are usually of the brown moss group. Low shrubs can be present with relatively low cover. The underlying peat ranges from moderately to poorly decomposed and nutrient status from eutrophic to oligotrophic. The water table is usually at the soil surface (Jeglum et al., 1974). The following example from St. Louis County (Kurmis et al., 1978) has some marsh characteristics as indicated by the presence of *Typha latifolia*, *Carex rostrata*, *Scirpus cyperinus*, and others:

Shrubs

Salix candida
Salix discolor
Salix serrissima

Forbs

Acorus calamus
Campanula uliginosa
Ceratophyllum echinatum
Cicuta bulbifera
Epilobium leptophyllum
Galium trifidum
Iris versicolor
Liparis loeselii
Lycopus uniflorus
Lysimachia thyrsiflora
Polygonum amphibium

Forbs (cont.)

Polygonum hydropiperoides
Potentilla palustris
Rumex sp.
Scutellaria epilobiifolia
Scutellaria lateriflora
Typha latifolia

Grasses, Sedges

Carex lasiocarpa
Carex rostrata
Carex sp.
Eriophorum sp.
Scirpus cyperinus
Sparganium eurycarpum

Ferns, Fern Allies

Equisetum fluviatile

Wooded Fen

This vegetation type could be characterized as nearly pure, open stands of stunted tamarack. According to Fox et al. (1977) the tree cover ranges from 5 to 25 percent. Bog birch is the dominant tall shrub species. *Chamaedaphne calyculata* and *Andromeda glaucophylla* are usually the most conspicuous species in the low shrub layer. Hummocks of sphagnum are common. *Menyanthes trifoliata* and *Utricularia* occupy pools between the hummocks. Wooded fen (poor swamp forest) occurs as a wide zone downslope from rich swamp forest and transitions between the two are usually gradual (Heinselman, 1970). However, transitions to treeless bog and muskeg (wooded bog) types are usually abrupt. Heinselman's (1970) description of poor swamp forest seems to characterize rather well the floristic composition of wooded fen:

Trees

Larix laricina
Picea mariana
Thuja occidentalis

Shrubs

Betula pumila
Lonicera villosa
Rhamnus alnifolia
Salix candida
Salix pedicellaris
Salix spp.

Half Shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Gaultheria hispidula
Kalmia polifolia
Ledum groenlandicum
Myrica gale
Vaccinium oxycoccos
Vaccinium vitis-idaea
var. *minus*

Forbs

Arethusa bulbosa
Aster junciformis
Cornus canadensis
Cypripedium spp.
Drosera rotundifolia
Galium labradoricum
Habenaria dilatata
Iris versicolor
Menyanthes trifoliata
Potentilla palustris
Rubus acaulis
Rubus pubescens
Sarracenia purpurea
Scutellaria galericulata
Smilacina trifolia
Typha latifolia
Utricularia spp.
Viola renifolia

Grasses, Sedges

Carex lasiocarpa
Carex limosa
Carex livida
Carex oligosperma
Carex spp.
Eriophorum spp.
Phragmites communis
Rhynchospora alba
Scheuchzeria palustris

Ferns, Fern Allies

Equisetum fluviatile
Thelypteris palustris

Mosses, Lichens

Pleurozium schreberi
Polytrichum spp.
Sphagnum fuscum
Sphagnum magellanicum
Sphagnum spp.

String Fen and Bog

The string fen or ribbed bog complex as defined by Fox et al. (1977) is a physiognomic group or landscape type. Floristically, ridges of these areas are sites of bog shrubs and sphagnum mosses, and may be dominated by tamarack or white-cedar (Heinselman, 1970). Less conspicuous ridges are slightly elevated graminoid areas (Hofstetter, 1969), sometimes with bog birch and other shrubs. The hollows between the ridges are the site of aquatic and semi-aquatic plants such as buckbean (*Menyanthes trifoliata*) bladderworts (*Utricularia spp.*) and sedges such as *Carex limosa* and *Carex livida*.

A plant list from a cedar string bog and fen vegetation type of Myrtle Lake peatland study area in Koochiching County (Heinselman, 1970) illustrates this complex:

Trees

Thuja occidentalis
Larix laricina
Picea mariana

Shrubs

Betula pumila
Lonicera villosa
Rhamnus alnifolia
Salix spp.

Half Shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Kalmia polifolia
Ledum groenlandicum
Vaccinium oxycoccos
Vaccinium vitis-idaea var. *minus*

Forbs

Arethusa bulbosa
Aster junciformis
Drosera rotundifolia
Iris versicolor
Menyanthes trifoliata
Potentilla palustris
Rubus acaulis
Sarracenia purpurea
Smilacina trifolia
Typha latifolia
Utricularia spp.

Grasses, Sedges

Carex lasiocarpa
Carex limosa
Carex livida
Carex spp.
Eriophorum spp.
Phragmites communis
Rhynchospora alba

Grasses, Sedges (cont.)

Scheuchzeria palustris
Scirpus hudsonianus

Ferns, Fern Allies

Equisetum fluviatile
Thelypteris palustris

Mosses, Lichens

Pleurozium schreberi
Polytrichum spp.
Sphagnum magellanicum
Sphagnum spp.

Another peatland feature is the occurrence of islands of bog forest, separated by fen areas. The islands are either small and dominated by tamarack or black spruce, or are larger with black spruce bog forest on the margins and stunted muskeg in the center (Hofstetter, 1969; Heinselman, 1963b, 1970). The smaller islands are typically in large fens such as those near Upper Red Lake. These islands range from about 20 x 50 ft. to 50 x 500 ft. with the major axis parallel to the general water flow (Heinselman, 1970). Older trees (either tamarack or black spruce) are clustered in the upstream "head" of the island. The tapered downstream "tail" of the island is occupied by shrubs, sphagnum hummocks and seedlings and saplings of tamarack of black spruce on the higher hummocks (Hofstetter, 1969). Griffin (1975) studied a tamarack forest, brush tail and sedge fen vegetation type in Upper Red Lake area, Beltrami County. The species composition of this complex follows:

Trees

Larix laricina

Shrubs

Betula pumila
Lonicera villosa
Salix pedicellaris

Half Shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Ledum groenlandicum
Rubus acaulis
Vaccinium oxycoccos

Forbs

Calla palustris
Campanula aparinoides
Drosera intermedia
Drosera rotundifolia
Epilobium palustre
Galium labradoricum
Hypericum virginicum
Lysimachia thyrsiflora
Menyanthes trifoliata
Potentilla palustris
Sarracenia purpurea
Smilacina trifolia
Stellaria longifolia
Typha latifolia
Utricularia intermedia
Utricularia minor
Viola blanda

Grasses, Sedges

Carex disperma
Carex interior
Carex lasiocarpa
Carex sp.
Eleocharis sp.
Phragmites communis
Rhynochospora alba
Scheuchzeria palustris
Triglochin maritima

Ferns, Fern Allies

Dryopteris thelypteris

Mosses, Lichens

Sphagnum spp.

Swamp Shrubs

Tall shrubs form the dominant plant cover, but there is a wide range of vegetative characteristics among the plant communities of the swamp shrub (thicket) type. This reflects a wide range of nutrient conditions (Figure 1). Swamp shrub position in the edaphic field in terms of moisture is between swamp hardwoods and swamp conifers and treeless fen communities (Figure 1). Leading dominants are *Alnus rugosa, Salix spp., Cornus stolonifera,* and *Betula pumila*. A few scattered tamarack, paper birch or other trees may be present. Half shrub and herb vegetation varies from one site to another depending on nutritional status of the site and shrub density. A plant list of the swamp shrub community, *Cariceto--Betuletum pumilae,* described by Janssen (1967) in Clearwater County, follows:

Trees

Larix laricina

Shrubs

Alnus rugosa
Betula pumila
Ribes triste
Salix candida
Salix gracilis
Salix interior

Forbs

Aster junciformis
Calla palustris
Campanula uliginosa
Cicuta bulbifera
Epilobium leptophyllum
Eupatorium maculatum
Galium labradoricum
Lysimachia thyrsiflora
Potentilla palustris
Stellaria longifolia

Grasses, Sedges

Carex diandra
Carex hystricina
Carex rostrata

Ferns, Fern Allies

Dryopteris thelypteris

Swamp Hardwoods

The major type in this group consists of black ash forest with American elm (*Ulmus americana*), balsam poplar (*Populus balsamifera*), white-cedar and balsam fir as minor associates. It occurs on marginal peatlands forming a transition to upland sites. The typical soil is poorly drained sedge peat of varying depth. The nutritional status is high as compared to swamp conifer types (Fig. 1). Tall shrub cover is sparse, and the ground vegetation layer is dense and rich in species diversity. A plant list of this type from a study area in Voyageurs National Park, St. Louis County (Kurmis et al., 1978) follows:

Trees

Fraxinus nigra
Abies balsamea
Picea glauca
Thuja occidentalis
Ulmus americana
Betula papyrifera
Populus balsamifera

Shrubs

Acer spicatum
Corylus cornuta
Lonicera canadensis
Prunus virginiana
Ribes americanum
Ribes oxyacanthoides
Ribes triste
Viburnum trilobum

Half Shrubs, Vines

Parthenocissus quinquefolia
Rubus strigosus

Forbs

Actaea rubra
Amphicarpa bracteata
Aralia nudicaulis
Aralia racemosa
Arisaema atrorubens
Asarum canadense
Aster umbellatus
Caltha palustris
Cicuta bulbifera
Circaea alpina
Epilobium glandulosum
Fragaria virginiana
Galium asprellum
Galium triflorum
Geum rivale

Forbs (cont.)

Habenaria psycodes
Impatiens capensis
Lycopus uniflorus
Lysimachia terrestris
Lysimachia thyrsiflora
Maianthemum canadense
Mentha arvensis
Mitella nuda
Orchis rotundifolia
Osmorhiza claytoni
Ranunculus pensylvanicus
Rubus pubescens
Sanicula marilandica
Scutellaria lateriflora
Trientalis borealis
Viola sp.

Grasses, Sedges

Carex gracillima
Carex intumescens
Carex sp.
Cinna latifolia

Ferns, Fern Allies

Athyrium filix-femina
Botychium virginianum
Dryopteris disjuncta
Dryopteris spinulosa
Equisetum arvense
Equisetum sylvaticum
Matteuccia struthiopteris var. *pensylvanica*

Mosses, Lichen

Mnium sp.
Ptilium sp.
Rhitidiadelphus triquetrus

Swamp Conifers

This broad group is usually subdivided into white-cedar, tamarack, and black spruce swamp forests depending on the principal dominant species. It merges with mixed conifer-deciduous forests of mineral soils along the peatland margins and with poor swamp forest towards the interior (Heinselman, 1970). The nutritional relationships of different swamp conifer types are shown in the edaphic field (Fig. 1).

White-cedar Forest

This type usually occurs as relatively small pure stands in drainage-ways where good supplies of nutrients and oxygen are available in the seepage waters. White-cedar is also found as a low tree beneath scattered and taller black spruce. Balsam fir, paper birch, black ash are minor associates. Abundance of speckled alder, half shrubs, forbs and graminoids varies with stand density. A plant list from a study area in Koochiching County (Janssen, 1967) characterizes this type:

Trees

Thuja occidentalis
Picea mariana
Abies balsamea
Fraxinus nigra

Shrubs

Alnus rugosa
Cornus stolonifera
Rhamnus alnifolia

Half Shrubs, Vines

Oxycoccus quadripetalus
Rubus pubescens

Forbs

Aster puniceus
Bidens cernua
Caltha palustris
Cicuta bulbifera
Coptis groenlandica
Cornus canadensis
Epilobium glandulosum
Impatiens capensis
Linnaea borealis
Lycopus americanus
Lycopus uniflorus
Mitella nuda
Scutellaria epilobiifolia
Smilacina trifolia

Grasses, Sedges

Calamagrostis canadensis
Carex disperma
Carex interior
Glyceria striata

Ferns, Fern Allies

Dryopteris thelypteris

Mosses, Lichens

Sphagnum sp.

Tamarack Forest

This type is characterized by a good-growth, closed forest of tamarack as distinguished from the stunted-growth open tamarack stands in the wooded fen (poor swamp forest) type. Tamarack swamps are floristically rich and, except for the dominant tree species, can be ecologically similar to swamp shrubs, black spruce - alder, and white-cedar types (Fig. 1). A plant list of a tamarack community in Beltrami County illustrates the species composition of this type (Bakuzis, 1959):

Trees

Larix laricina
Abies balsamea
Betula papyrifera
Thuja occidentalis
Ulmus americana

Shrubs

Alnus rugosa
Betula pumila
Cornus stolonifera
Corylus cornuta
Lonicera canadensis
Lonicera oblongifolia
Ribes americanum
Ribes hirtellum
Salix discolor

Half Shrubs, Vines

Parthenocissus inserta
Rubus strigosus

Forbs

Aster novae-angliae
Caltha palustris
Campanula aparinoides
Circaea alpina
Eupatorium maculatum
Fragaria virginiana
Galium trifidum
Galium triflorum
Geum sp.
Impatiens capensis
Linnaea borealis
Lysimachia thyrsiflora

Forbs (cont.)

Mentha arvensis
Mitella nuda
Potentilla palustris
Pyrola secunda
Rubus pubescens
Smilacina trifolia
Stellaria longifolia
Trientalis borealis
Typha latifolia
Viola renifolia

Ferns, Fern Allies

Athyrium filix-femina
Botrychium virginianum
Cystopteris bulbifera
Dryopteris cristata
Dryopteris spinulosa
Equisetum palustre

Mosses, Lichens

Dicranum sp.
Mnium sp.
Pleurozium schreberi

Black spruce - alder forest

This type usually has a conspicuous speckled alder layer in the undergrowth but can also be rich in other shrubs. A rich herbaceous flora is the other distinguishing feature and several grasses, sedges and ferns are typical. Mosses are less abundant than in other black spruce types. *Sphagnum spp.* create loose hummocks, especially around alder clumps. *Pleurozium schreberi* and *Dicranum* carpet the hummocks around the bases of trees (Heinselman, 1963b). Tamarack and white-cedar may be components of the tree layer. These mixtures often mark a transition from black spruce to white-cedar and tamarack types. The black spruce stands are of good quality but are frequently understocked (Heinselman, 1963b). A plant list featuring this type is from the Lake of the Woods County (Kratz, 1977). It has the characteristic components of black spruce - alder type except for speckled alder:

Trees

Picea mariana
Larix laricina
Thuja occidentalis

Shrubs

Amelanchier sp.
Cornus stolonifera
Lonicera oblongifolia

Shrubs (cont.)

Lonicera villosa
Rhamnus alnifolia
Salix spp.

Half Shrubs, Vines

Andromeda glaucophylla
Ledum groenlandicum
Rubus pubescens
Rubus strigosus
Vaccinium oxycoccos
Vaccinium vitis-idaea var. *minus*

Forbs

Aster junciformis
Campanula aparinoides
Chelone glabra
Coptis trifolia
Cornus canadensis
Cypripedium spp.
Drosera rotundifolia
Epilobium strictum
Galium labradoricum
Galium triflorum
Habenaria dilatata
Linnaea borealis
Listera cordata
Lysimachia thyrsiflora

Forbs (cont.)

Maianthemum canadense
Mitella nuda
Petasites sagittatus
Potentilla palustris
Pyrola spp.
Sarracenia purpurea
Smilacina trifolia
Trientalis borealis
Viola sp.

Grasses, Sedges

Carex spp.
Eriophorum spp.
Gramineae

Ferns, Fern Allies

Equisetum fluviatile
Thelypteris palustris

Mosses, Lichens

Dicranum sp.
Pleurozium schreberi
Polytrichum spp.
Sphagnum spp.

Black spruce - Feather moss forest

This type is mature black spruce forest. Trees are tall, dense and nearly even-aged. Low shrubs are sparse. Beneath small openings in the tree canopy are a few *Ledum groenlandicum, Vaccinium spp.* and *Gaultheria hispidula.* A continuous moss carpet of *Pleurozium schreberi,* other feather mosses, and patches of sphagnum are typical of this swamp conifer forest. This community is the principal black spruce pulpwood resource of Minnesota

(Heinselman, 1963b, 1970). According to Heinselman (1970) this type merges upslope gradually with sphagnum-black spruce-leatherleaf bog (black spruce-sphagnum, wooded bog) and downslope it may merge with rich swamp forest (black spruce - alder forest). Figure 1 shows the edaphic relationships of this type to black spruce - alder and black spruce - sphagnum types occupying an intermediate position. A plant list from the Myrtle Lake peatland study area in Koochiching County (Heinselman, 1970) characterizes this forest type:

Trees

Picea mariana
Larix laricina

Half Shrubs, Vines

Andromeda glaucophylla
Chamaedaphne calyculata
Gaultheria hispidula
Kalmia polifolia
Ledum groenlandicum
Vaccinium angustifolium
Vaccinium myrtilloides
Vaccinium Oxycoccos
Vaccinium vitis-idaea var. *minus*

Forbs

Sarracenia purpurea
Smilacina trifolia

Grasses, Sedges

Carex spp.
Eriophorum spp.

Ferns, Fern Allies

Lycopodium annotinum

Mosses, Lichens

Cladonia spp.
Dicranum rugosum
Hylocomium splendens
Pleurozium schreberi
Polytrichum spp.
Sphagnum fuscum
Sphagnum magellanicum
Sphagnum spp.

Black spruce - Sphagnum Forest

A similar type in the Fox et al. (1977) system is black spruce - raised bog which includes areas that are too fine to be mapped into vegetative components at a scale of 1:24000. It represents a mixture of black spruce -

feather moss and wooded bog (muskeg) types. As delineated in the edaphic field (Fig. 1), communities in the black spruce - sphagnum type show over 25 percent tree cover and more than 75 percent sphagnum cover. The nutrient levels of these communities are similar to those of wooded and treeless bog types, however, there is a trend towards drier site conditions with increased stand density (Fig. 1). A species list of a black spruce bog forest in Cook County (Dean, 1971) follows:

Trees

Picea mariana
Larix laricina

Shrubs

Alnus rugosa
Betula pumila

Half Shrubs, Vines

Chamaedaphne calyculata
Gaultheria hispidula
Kalmia polifolia
Ledum groenlandicum
Vaccinium angustifolium
Vaccinium myrtilloides
Vaccinium oxycoccos

Forbs

Listera cordata
Menyanthes trifoliata
Sarracenia purpurea
Smilacina trifolia

Grasses, Sedges

Carex pauciflora
Carex paupercula
Carex trisperma
Eriophorum spissum

Mosses, Lichens

Pleurozium schreberi
Ptilium crista-costrensis
Sphagnum spp.

UNIQUE PLANT SPECIES AND AREAS

Of concern in peatland preservation is the presence of any unique, rare, or uncommon plant species and communities. The extensive peatlands of northern Minnesota contain areas still relatively undisturbed by human activity. Peatland flora have developed patterns and associations under natural influences since the last ice age. It is desirable that unique plant species and communities native to our peatlands be preserved. This section is devoted to a review of those species considered to be of special interest.

Species Categories

Several references have been consulted as the primary sources of information as to the relative degree of rarity of plant species including Morley (1972), Moyle (1973 and 1975), and Smithsonian Institution (1975). The terminology describing relative rarity is not standardized among authors and public agencies. The following system from Moyle (1973 and 1975) was found most useful:

Endangered: Those species in danger of extinction in Minnesota within the immediate future.

Threatened: Those species which could become endangered in Minnesota in the foreseeable future but not necessarily throughout their entire natural range.

Rare: Those species or subspecies which are rare, uncommon, or local in Minnesota, but not necessarily so over their entire natural range. Such species are not, as far as is known, endangered. Rare is a geographic term as opposed to endangered, which is a genetic term.

Merits Special Consideration: A species or subspecies which, because of its recognized status and value and because of general appreciation by the public, is of exceptional interest. Such a species therefore merits special consideration in DNR programs. Examples include the loon, timber-wolf, and showy lady's-slipper. Endangered status is not implied.

Status Changing: Species so listed are probably less abundant than formerly, but are neither endangered nor rare. Status and abundance should be watched, more information gathered, and protection or special management given if this proves necessary.

Peripheral: Representatives of species which are near the edge or limit of their natural range in Minnesota. Here such individuals can be expected to be rare or local due to natural conditions and competition with better adapted species.

Local: Species tending to be concentrated in areas of suitable habitat; may be uncommon or absent elsewhere in their Minnesota range.

These categories help define the distributional status of those species considered in this report.

Species of Special Concern

In connection with the objectives of this project it was felt necessary to select a list of individual plant species for special preservation in Minnesota's northern peatlands. Because not all peatland authorities are agreed on the relative rareness of individual species, and more importantly, because of the paucity of plant collections from the peatlands, it is difficult to select a list on which there will be total agreement.

Several considerations were involved in selecting 10 species of "special concern." Obviously, only species which are present on Minnesota's northern peat areas were considered. Secondly, has the species been classed as endangered or threatened on either the Smithsonian (federal) or the Minnesota DNR lists? A third concern, does it have legally protected status in Minnesota? Consideration was also given to whether a species was found on upland as well as on peatland sites. Some species, such as the Trilliums, were not included on the final list because, although they are legally protected species in Minnesota, they are fairly common on upland sites. For the same reason some of the orchids were not rated in the final list of species of special concern.

The species finally selected are listed in Tables 4, 5, and 6. Based on information abstracted from botanical literature, Table 4 lists suggested biological status of selected peatland plant species. Each of the species in Table 4 is further discussed in this report. Information on the biological status and habitat for each plant, as drawn from the literature, is given in the following outline arrangement.

Table 4. Peatland Plant Species of Special Concern[1]

Latin Name	Common Name	Proposed Category
Polemonium occidentale (Greene) var. *lacustre* (Wherry) Lakela	Western Jacob's Ladder	Rare. Could become endangered if known site was disturbed.
Cypripedium arietinum R. Brown	Ram's-Head Lady's-Slipper	Rare or local. May merit special consideration as an orchid of aesthetic interest.
Malaxis paludosa (Linnaeus) Swartz	Bog-adder's Mouth	Rare. Actual degree of abundance or rarity not known with certainty.
Orchis rotundifolia Banks ex Pursh	Small Round-leaved Orchis	Rare or local. May merit special consideration as an orchid of aesthetic interest.
Calypso bulbosa (Linnaeus) Oakes	Calypso Orchid, Fairy Slipper	Rare or local. May merit special consideration as an orchid of aesthetic interest.
Cypripedium reginae Walter	Showy Lady's-Slipper	Merits special consideration as the State Flower.
Arethusa bulbosa Linnaeus	Swamp Pink, Dragon's Mouth	Possibly Rare or local. Conflicting reports exist on degree of abundance or rarity.
Vaccinium vitis-idaea var. *minus* Lodd	Lingberry	Peripheral in northern Minnesota. Not uncommon further north in Canada.
Cladium mariscoides (Muhl.) Torr	Twig-Rush, Water Bog Rush	May be Peripheral and local. Actual degree of abundance or rarity not known.
Drosera linearis Goldie	Slender-leaved Sundew	Local in northern Minnesota. Formerly known only from Hennepin County.

[1](Species nomenclature from Gray's Manual of Botany, 8th edition, 1950.)

Polemonium occidentale (Greene) var. *lacustre* (Wherry) Lakela (listed as *P. caeruleum* var. *occidentale* in University of Minnesota Botany Department Herbarium records.)

Common name: Western Jacob's Ladder

Status in botanical literature:

Considered Endangered in 1975 Smithsonian list of plants proposed for national Endangered or Threatened status.

Considered Endangered in 1976 USDA Fish and Wildlife Service list of plants proposed for national Endangered status.

Described as "rare; extension of a western species" and known only from a single site in Minnesota (Lakela, 1965).

Habitat information:

Known in Minnesota from a white-cedar swamp 3½ miles north of Sturgeon Lake, about 25 miles north of Hibbing (Lakela, 1965).

"Arbor vitae swamp, St. Louis County, Minnesota." (Fernald, 1950)

Cypripedium arietinum R. Brown

Common name: Ram's-head Lady's-slipper

Status in botanical literature:

Considered Threatened in 1975 Smithsonian list.

Considered a Species of Special Interest (Moyle, 1975).

Included as one of the "Endangered and Threatened Orchids of the United States" (Ayensu, 1975).

"This small species is rare and local, confined to the cold forests of the Northeast" (Luer, 1969).

"Although occasionally locally abundant, the nearly legendary ram's-head lady's-slipper remains a rare orchid" (Luer, 1975).

"The flowers of this rare species are among the most short-lived of all our native orchids" (Correll, 1950).

"This smallest native *Cypripedium* is one of the most primitive and fascinating. It has long been considered rare, especially in some areas where it occurs; yet in the heart of its range (upper Michigan) it is sometimes common" (Case, 1964).

Habitat information:

"Two distinct habitats; rich cedar (*Thuja*) mires, growing in the wet sphagnum floor with other orchids; or thin dry soil over limestone or beachsand, always partially shaded." (Luer, 1975).

"A plant of cool subacid or neutral soils. Two basically different habitats: (1) cool, dense, balsam-cedar-spruce swamps where mosses, creeping snowberry, Labrador-tea, and twinleaf abound. Here it grows as a single flowering stem, rarely in a clump...here it attains its largest size. (2) Nearly pure sand, mulched with pine or cedar needles (north hillsides in jack pine forest is typical). In such localities, this orchid reaches a peak of abundance." (Case, 1964).

Damp or mossy woods or bogs (Fernald, 1950).

"...an inhabitant of cold, sphagnous, cedar, tamarack and arbor vitae swamps and bogs,...also found in damp or dry coniferous forests as well as evergreen heath areas and wooded rocky slopes." (Correll, 1950).

Moist, usually acid soils in coniferous woods, Cook, Aitkin, Clearwater, Becker, Isanti, Anoka, Wright and Hennepin counties (Morley, 1969).

Malaxis paludosa (Linnaeus) Swartz

Common name: Bog-adder's mouth

Status information:

"*Malaxis paludosa* is exceedingly difficult to find. Not only is it local and rare, but very inconspicuous because of its tiny stature and greenish color." Mainly a species of northern Canada, its range is shown to extend into the United States only in northern Minnesota, and in Alaska (Luer, 1975).

Considered "rare in Minnesota and all of North America" (Morley, 1972).

"Regarded by many botanists as one of the rarest plants in the North American flora, this orchid has recently been found in several places in northern Canada and may prove to be more overlooked than rare." (Case, 1964).

"This Eurasian bog orchid is exceedingly rare and elusive." (Correll, 1950).

Known in Minnesota only from sphagnum bogs in Otter Tail and Clearwater counties (Moyle, 1975).

Habitat information:

"Usually grows in open, sunlit, acid sphagnum bogs where its roots can be kept cold and continually wet. At its farthest

south limits (northern Minnesota), it may be found in shaded wet woods." (Luer, 1975).

"Exceedingly rare, local in Lake Itasca area of Minnesota, Thunder Cape area of Sibley Peninsula, Lake Superior, Alberta, and Alaska. Openings in bogs and muskegs, usually in black spruce-balsam fir-cedar cover. Frequently grows in very wet, turfy spots of moss (rarely sphagnum). Normally a sun lover, but has been found in dark, mossy wells in deep shade." (Case, 1964).

"Apparently confined to spongy turfy bogs and muskegs or exceedingly wet forests." (Correll, 1950).

"In wet sphagnum; northern Minnesota and adjacent Ontario, Alaska." (Fernald, 1950).

Orchis rotundifolia Banks *ex* Pursh.

Common name: Small Round-leaved Orchis

Status information:

Grows dwarfed but abundant on cold open tundra of the far north. Towards the southern limits of its range, becomes increasingly rare in increasingly sheltered habitats. Northern Minnesota is one of the southern limits of this species' range (Luer, 1975). Confined to cold northern coniferous forests and bogs. While abundant locally in the Canadian Rocky Mountain areas, it is strictly rare and local in the Great Lakes region (Case, 1964).

"In the northeastern U.S. the Small Round-leaved Orchis is one of the rarest orchids occurring there. It is more frequent in parts of its western range." (Correll, 1950).

Habitat information:

(In Minnesota) plants are restricted to shaded bogs where cool, moist beds of sphagnum moss offer summer air-conditioning. Good drainage of a constant water supply over sufficient lime is essential, as the roots cannot tolerate heat nor acid (Luer, 1975). Moist woods and swamps, St. Louis County, and from southern Beltrami and Clearwater to Becker and northeast Otter Tail counties, and in Isanti County (Morley, 1969).

"Cold soil is the conspicuous unvarying feature of its habitats. At the southern edge of its range, it inhabits very cold balsam fir-balck spruce-white-cedar bogs almost exclusively. Considerable sphagnum is typically present at the surface but usually there are underlying layers of marl (calcareous deposits). North of Lake Superior it becomes more frequent. In this colder region it occurs in more acid and more open sphagnous situations, in black spruce or spruce-cedar bogs. Even here it tends to grow along streams in mosses other than sphagnum." (Case, 1964).

"The places where the Small Round-leaved Orchis grows are characterized by a cool summer climate, an unfailing supply of moisture accompanied by good drainage, and sufficient lime to keep the soil pH near neutral. This species inhabits cold moist or

wet forests, commonly in calcareous regions. It is often found in cedar, spruce, or tamarack swamps and bogs." (Correll, 1950).

Mossy calcareous swamps and woods. Range: Newfoundland to Yukon, locally south to New Brunswick, northern New England (and formerly New York), Wisconsin, Minnesota, and Montana. (Fernald, 1950).

Calypso bulbosa (Linnaeus) Oakes

Common name: Calypso Orchid, Fairy Slipper

Status information:

In northeastern North America, as in Eurasia, this orchid is rare and local in the shade of inaccessible, damp forests. (Luer, 1975).

Rare near any populated area (Case, 1964).

Rare, usually inhabiting a secluded area (Correll, 1950).

Range: Labrador to Alaska, and (now very locally) to west Newfoundland, Nova Scotia, northern New England, northern New York, Michigan, Wisconsin, Minnesota, Arizona and California (Fernald, 1950).

Habitat information:

In shaded, damp forests...roots are in loose moss or in rotting humus of the forest floor (Luer, 1975).

Shaded mesic to moist coniferous forests, Cook to Koochiching, Clearwater, northern Cass, and Carlton counties (Morley, 1969).

White-cedar forests (Lakela, 1965).

In cool soils only. Grows in old, undisturbed, heavily wooded spruce-balsam-cedar swamps, or in evergreen woods along Great Lakes shores. In bogs may be found on small islands of drier soil. Does not grow in soggy soils or sphagnum moss. In our region the largest colonies grow in rather dry cedar and fir thickets along the upper lakes shores, especially in limestone areas (Case, 1964).

Prefers a cool, moist, circumneutral humus soil where the sun does not heat the litter above 60°F in the summer. This species is found growing in mosses on the floor of cool, moist coniferous forests; in tamarack and cedar swamps, bogs, and in damp spruce-aspen forests (Correll, 1950).

Cool, mossy woods, chiefly calcareous, often about the bases of *Thuja* (Fernald, 1950).

Cypripedium reginae Walter

Common name: Showy Lady's-Slipper

Status information:

The Minnesota State Flower and as such, considered a "Species of Special Interest" (Moyle, 1975).

Our largest, and possibly most spectacular, native orchid. Within its range it is sometimes found in great colonies in clearings which serve as deer yards in winter, the trampling action of deer hooves thought to plant the seeds at an optimum germination depth (Luer, 1975).

One of the best known and most popular of wildflowers. Of wide spread distribution in eastern North America (Case, 1964).

Habitat information:

A typical habitat is an open area near the margin of a wet bog. Some sunlight and a constant supply of water are necessary. When growing in acid sphagnum bogs, the orchid's roots are deep below the acid surface, in relatively neutral underlying peat or soil (Luer, 1975).

Swamps, bogs, or moist woods, St. Louis to Kittson County, south to Becker, Kandiyohi, Nicollet, Waseca, Fillmore, and Winona counties (Morley, 1969).

In sphagnum bogs; *Picea mariana* bog; white-cedar forest (Lakela, 1965).

A bog plant, chooses the wettest open situations available. In a variety of wet habitats, most abundant in openings in balsam fir-cedar-tamarack swamps when these are not too acid. Definitely not a plant of intensely acid sphagnous black spruce bogs. Neutral to slightly alkaline black bog mucks and marls are favorite soils (Case, 1964).

This species seems particularly abundant in the balsam-spruce-tamarack swamps in the Lake States region where colonies of several thousand flowering plants are occasionally to be found. Usually found in wet neutral or limestone soils in cedar, larch, or tamarack swamps and bogs (Correll, 1950).

Mossy (chiefly calcareous) swamps, bogs or woodland glades (Fernald, 1950).

Arethusa bulbosa Linnaeus

Common name: Swamp Pink, Dragon's Mouth, Arethusa

Status information:

Populations fluctuate considerably. The plant is thought to be short-lived, relying on seed production for propogation (Luer, 1975).

(In) sphagnum bogs and swampy meadows, usually uncommon (Morley, 1969).

"There are conflicting reports on the abundance of *Arethusa*. Some authors call it rare; others, common. Actually, blooming populations of this orchid can fluctuate considerably at a given station" (Case, 1964).

"Rapidly becoming extinct (the bulbs only loosely attached in moss) south of Newfoundland and Canada" (Fernald, 1950).

Rare (in northeastern Minnesota) (Lakela, 1965).

Habitat information:

A typical northern habitat is a quaking bog of sphagnum with a remnant pond, encircled by tamarack and black spruce. Common companion plants are *Pogonia ophioglossoides, Calopogon pulchellus,* sundews and pitcher plants (*Drosera sp.* and *Sarracenia sp.)* (Luer, 1975).

Sphagnum bogs and swampy meadows, usually uncommon, Cook to Beltrami and Aitkin counties, and in Chisago and Hennepin Counties (Morley, 1969).

Deep, open, sunny sphagnum bogs, especially in black spruce-tamarack bogs surrounding small lakes. Preferred habitat is near open water. In sphagnum bogs its frequent companions are pitcher plant, cranberry, leather-leaf, sundews, rose pogonia, and the fringed-orchids (Case, 1964).

Arethusa is a true bog plant. Its typical habitat is in deep sphagnum moss in company with ericaceous shrubs. It requires a bed of intensely acid sphagnum moss (Correll, 1950).

Sphagnous bogs and peaty meadows, Newfoundland to Ontario and Minnesota, south to Nova Scotia, New England, Long Island, Delaware, Maryland. Mountains to South Carolina, Ohio, northern Indiana, and Wisconsin, rapidly becoming extinct south of Newfoundland and Canada (Fernald, 1950).

Vaccinium vitis-idaea var. *minus* Lodd

Common name: Lingberry

Status information:

The species has been suggested for special status ("meriting special consideration") (Moyle, 1975).

Occurs occasionally from Lake Superior to Canadian border lakes (Lakela, 1965).

Locally abundant in sphagnum bogs in far northern parts of Minnesota and adjacent Canada. A subartic species at the periphery of its range in northern Minnesota (Rosendahl, 1955).

Habitat information:

Mostly in bogs and swamps, sometimes on drier ground or rocks, Cook to Lake of the Woods and Clearwater counties (Morley, 1969).

(Found in) sphagnum bog forest, sphagnaceous spruce forest, spruce-tamarack bog in deep moss. Range: Subarctic North American, south to New England, western Minnesota (Lakela, 1965).

Rocky or dry peaty acid soil, subarctic America, south to Newfoundland, Nova Scotia, New England, Lake Superior region of Ontario, northern Minnesota, Manitoba, Saskatchewan, Alberta, and British Columbia (Fernald, 1950).

Cladium mariscoides (Muhl.) Torr.

Common name: Water Bog Rush, Twig-Rush

Status information:

Known from Clearwater, Lake counties (Morley, 1972).

Rare (in northeastern Minnesota) (Lakela, 1965).

Habitat information:

Found on the shore of an island in Chippewa Lake, Lake County (Lakela, 1965).

Small circular "islands" of *Cladium mariscoides* with tamarack growing at the center were found in the fen area of the large peatland just north of the Upper Red Lake. The *Cladium*-tamarack

association seems to be a relatively recent phenomena. *Cladium* also occurs elsewhere on the Red Lake peatland (Hofstetter, 1969). "Swamps, marshes, and sandy shore or pond margins, either fresh or brackish. Range: Florida and Alabama, north to southwestern Newfoundland, Nova Scotia, south Quebec, northern Illinois, Minnesota and Saskatchewan" (Fernald, 1950).

Drosera linearis Goldie

Common name: Slender-leaved Sundew

Known from Hennepin County (Morley, 1972).

"Marly bogs and wet limey shores, local, western Newfoundland to south Alberta, south to Gaspe County, Quebec; south Aroostook County, Maine; Bruce County, Ontario; Michigan, Wisconsin, and Minnesota." (Fernald, 1950).

Drosera linearis is listed as one of the less common components of one of the "graminid furrow" community types of the ribbed fen in the Red Lake peatland (Hofstetter, 1969).

Habitat information:

Marly bogs and wet limey shores, local (in its range) (Fernald, 1950). Appears to be near the edge of its range in Minnesota. Described as less commonly present (with the more common *Drosera intermedia*) in a graminid furrow community where the water table is about level with the peat surface. The graminid community is dominated by sedges (*Carex lasiocarpa, C. limosa, C. livida, C. chordorrhiza,* with *Rhynchospora alba* and *Scheuchzeria palustris*) with some semi-aquatic plants and non-acidic mosses (Hofstetter, 1969).

It would be helpful to be able to predict in what peatland habitats each of these plant species would be likely to occur. However, current knowledge does not allow precise habitat prediction. Generalized habitat predictions can be made for most of these plants. Table 5 gives a description of their typical habitat in terms of five environmental factors; soil moisture, pH, soil nutrients, light intensity, and optimum soil temperature. These factors are evaluated in descriptive terms rather than with measured values because habitat descriptions in the botanical literature are almost entirely of a descriptive nature. Where information was judged to be insufficient, or where information on a factor conflicted, no evaluation was made.

Table 6 further defines typical habitat. Common plants typically associated with each species are listed. The habitat types for the species of interest are also related to units in two systems of peatland vegetation classification (Fox et al., 1977; and Heinselman, 1970).

Some of the reports of Minnesota peatland studies contain lists of species found in specific locations. From these lists a map showing their general locations was prepared (see Fig. 3). Considerable additional information on reported species occurrences was also obtained from herbarium records in the University of Minnesota Botany Department Herbarium (Ownbey, 1978).

Table 5 . Optimum Levels of Habitat Factors for Selected Peatland Species

Species	Soil Moisture	Soil Reaction	Soil Nutrients	Light	Soil Temperature
Polemonium occidentale var. lacustre	*	*	*	*	*
Cypripedium arietinum	Damp	Circum-Neutral to Acid	Intermediate	Partial Shade	Cool
Malaxis paludosa	Wet	Acid	Low	Open, Sunny	Cool
Orchis rotundifolia	Wet	Circum-Neutral	Intermediate	Partial Shade	Cold
Calypso bulbosa	Damp	Circum-Neutral	Intermediate	Dense Shade	Cool
Cypripedium reginae	Wet	Circum-Neutral	Intermediate	Partial Shade	*
Arethusa bulbosa	Wet	Acid	*	Open, Sunny	Cool
Vaccinium vitis-idaea var. minus	Wet	Acid	Low	Open, Sunny	Cool
Cladium mariscoides	Wet	Circum-Neutral	Intermediate	Open, Sunny	*
Drosera linearis	Wet	Circum-Neutral	Intermediate	Open, Sunny	*

* Indicates that information is insufficient, inconsistent, or conflicting.

Table 6. Plant Species and Habitats Associated with Peatland Species of Special Concern.

Species of Concern	Associates	Peatland Habitat Types
Polemonium occidentale var. *lacustre*	Insufficient information	*Thuja occidentalis* dominated swamp forest (Fernald 1950, Lakela 1965) Types: "Swamp-conifer Cedar-Spruce" (Fox 1977) "Rich Swamp Forest" (Heinselman 1970)
Cypripedium arietinum	*Gaultheria hispidula* *Ledum groenlandicum* (Case 1964)	Swamp Forest, dominated by *Picea mariana/Larix laricina/ Thuja occidentalis* and *Abies balsamea*. Mixture is typical (Case 1964) Types: Swamp conifer, Cedar-spruce Swamp conifer Tamarack (Fox 1977) Swamp conifer, Spruce-Feathermoss "Rich Swamp Forest" "Poor Swamp Forest" (Heinselman 1970)
Malaxis paludosa	Insufficient information	Found in sunny openings in *Picea mariana/Abies balsamea/ Thuja occidentalis* cover, in wet turfy spots of non-sphagnum moss, or on stumps or logs. (Case 1964) (Correll 1950) Types: "Swamp Conifer; Spruce-Feathermoss" (Fox 1977) "Poor Swamp Forest" "Black Spruce-Feathermoss Forest (Heinselman 1970)
Orchis rotundifolia	*Smilacina trifolia* *Ledum groenlandicum* *Listera cordata* *Habenaria obtusata* *Cypripedium reginae* *Malaxis unifolia*	On deep, wet sphagnum in *Picea-Larix* or *Thuja* bogs or swamp forests (Lakela 1965). Characteristically grows in beds of moss or at the bases of (*Thuja*) trees (Case 1964) Types: "Swamp Conifer; Cedar-Spruce" (Fox 1977) "Swamp conifer; Tamarack" "Rich Swamp Forest" "Poor Swamp Forest" (Heinselman 1970)
Calypso bulbosa	*Corallorhiza striata* *Goodyera repens* var. *ophioides* *Linnaea borealis* (Case 1964)	"Old, undisturbed, heavily wooded spruce-balsam-cedar swamps" ... "in bogs, found on drier soil, or around bases or sides of stumps. Not found in soggy soil or sphagnum moss (Case 1964) "In white cedar (*Thuja*) forests (in NE Minnesota) (Lakela 1965). Types: "Swamp, Conifer, Cedar-Spruce" (Fox 1977) "Rich Swamp Forest" (Heinselman 1970)
Cypripedium reginae	*Ledum groenlandicum* *Dryopteris thelypteris* *Andromeda glaucophylla* *Equisetum sp.* *Parnassia sp.* (Case 1964)	"Without open situations available Most abundant in openings in *Abies-Thuja-Larix* swamp forest where water is not too acid. Old winter deeryards are sites for some of the best colonies." (Case 1964) Types: "Swamp, Conifer Cedar Spruce" (Fox 1977) "Swamp, Conifer Tamarack" "Rich Swamp Forest" "Poor Swamp Forest" (Heinselman 1970)
Arethusa bulbosa	*Pogonia ophioglossoides* *Calopogon pulchellus* *Sarracenia purpurea* *Chamaedaphne calyculata* *Drosera spp.* *Vaccinium oxycoccos* *Vaccinium macrocarpon* (Luer 1975) (Case 1964) (Correll 1950)	"Deep, open, sunny sphagnum bogs; or *Picea-Larix* bog forest near open water." (Case 1964) Types: "Swamp-Conifer; Tamarack" "Bog, Muskeg" (Fox 1977) "Bog, Open" "Poor Swamp Forest" "Sphagnum-Black Spruce-Leatherleaf Bog Forest" (Heinselman 1970)
Vaccinium vitis-idaea var. *minus*	*Sarracenia purpurea* *Drosera rotundifolia* *Polytrichum sp.* *Chamaedaphne calyculata* *Andromeda glaucophylla* (Hofstetter 1969)	"Open sphagnum bogs" "*Picea-Larix* sphagnum bog forest in deep moss" (Rosendahl 1955; Lakela 1965) Types: "Bog, open" "Bog, Muskeg" (Fox 1977) "Swamp, Conifer; Tamarack" "Sphagnum-Black Spruce-Leatherleaf Bog Forest" "Black Spruce-Feathermoss Forest" (Heinselman 1970)
Cladium mariscoides	*Scorpidium scorpioides* *Sphagnum contortum* *Rhynchospora alba* *Larix laricina* (occasionally) (Hofstetter 1969)	Known from open, wet Fen areas in the Red Lake Peatland (north of Upper Red Lake). Found in circular clones in "bog drains" or broad, wet fen areas of slowly flowing water. The patterning typical of this fen area is not apparent in the area of *Cladium* colonization. (Hofstetter 1969) Types: "Open Fen" "String Fen" (Fox 1977) "Larch String Bog and Fen Complex" (Heinselman 1970)
Drosera linearis	*Carex lasiocarpa* *Rhynchospora alba* *Scheuchzeria palustris* *Campylium stellatum* *Drepanocladus intermedius* *Drosera intermedia* (Hofstetter 1969)	Occasionally found with *Drosera intermedia* (more common) in an area of patterned fen with dense *Graminoid* growth in the lower "furrows". *Carex lasiocarpa* is the dominant. (Hoffstetter 1969) Types: "Open Fen" (Fox 1977) "Cedar String Bog and Fen Complex" or "Larch String Bog and Fen Complex" (Heinselman 1970)

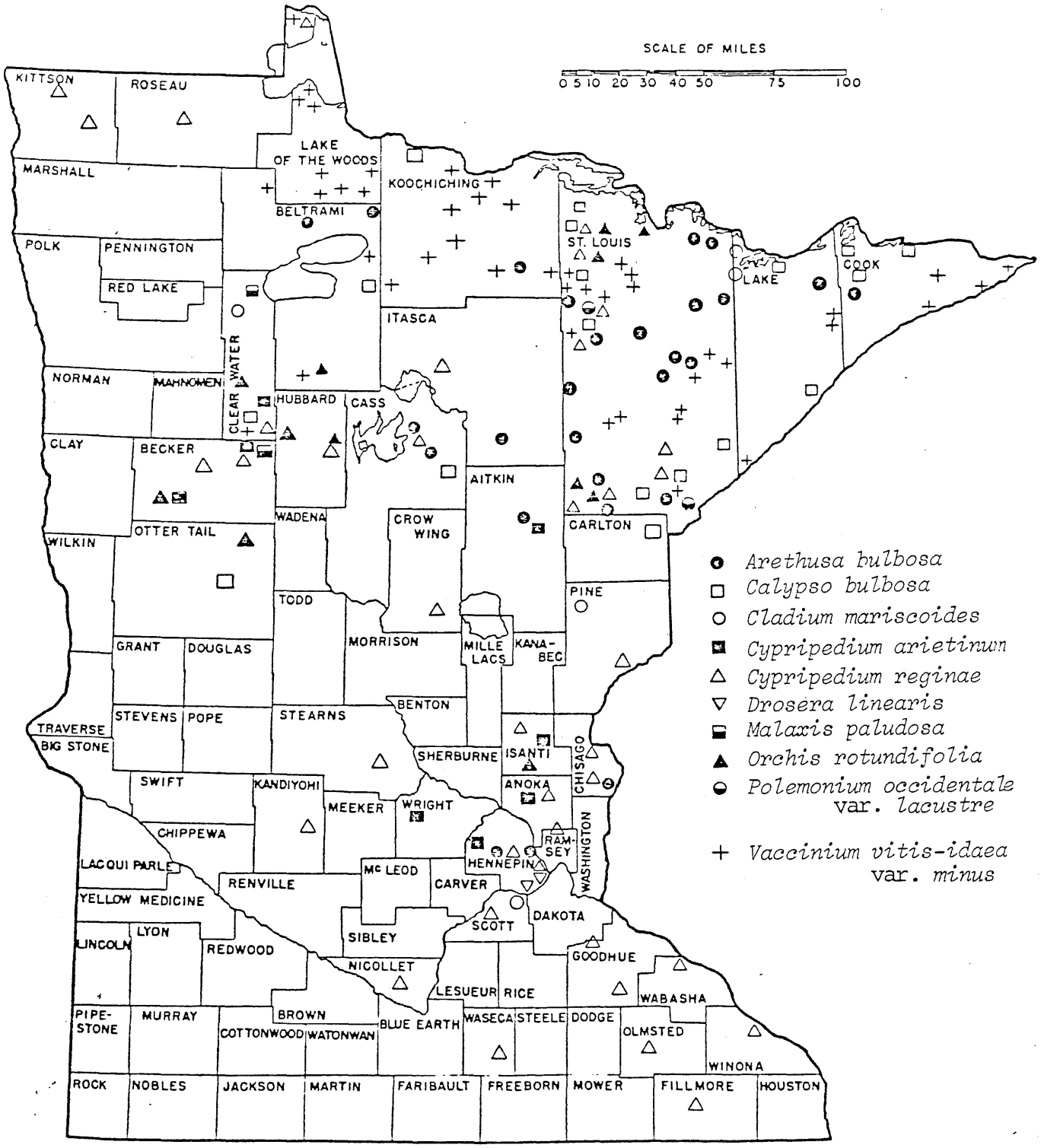

Figure 3. Reported Locations of Species of Special Concern.

Areas of Special Concern

In order to protect a species it is necessary to protect its habitat. This means that the areas containing the habitats needed should be identified and located. This section is devoted to summarizing all areas within the northern Minnesota peatlands which have been proposed for special protection by various sources.

Focusing attention on the area rather than on the individual species is also important because it provides for the preservation of the rare species in its total community. It makes little sense to make picking a rare species illegal if it is legally possible to destroy its habitat.

It is also important to identify areas of concern because of the need to preserve examples of various kinds of peatland communities and even larger total ecosystems. The first section of this report described various physiognomic aspects of peatlands; bogs, fens, swamps, and their subunits. These are equally in need of preservation as are individual species. Some features such as patterned bogs and string fens are present only as parts of large peatland areas where the water flow pattern gives rise to these various features. Disruption of the water movement by major drainage could destroy these vegetation patterns.

Figure 4 shows approximate locations of various areas which have been identified as having features which merit special protection. These include areas proposed, being processed, or accepted as Scientific and Natural Areas in the Minnesota system, as Critical Areas in the state system, or as National Natural Landmarks. Some areas are under two of these designations.

In the absence of an intensive inventory to identify areas of special significance it is felt that these areas, already recognized for their special natural features, should be given special preservation attention. Table 7 lists these areas by county and area category. More detailed information on each area is contained in DNR file records for Scientific and Natural Areas.

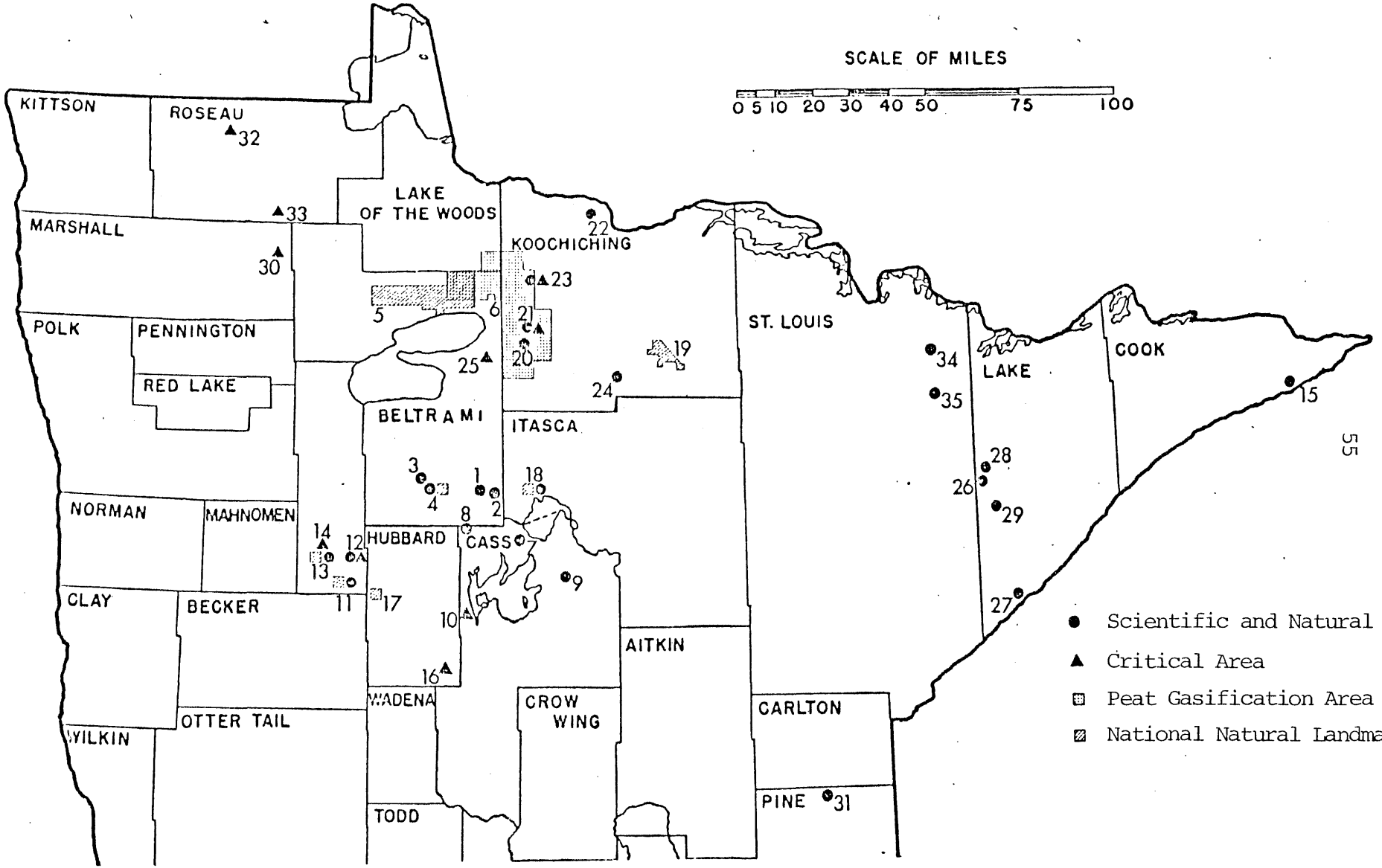

Figure 4. Location of Scientific and Natural Areas, Critical Areas, and National Natural Landmarks.

Table 7. Areas of Special Concern in Northern Minnesota Peatlands.

County		Scientific and Natural Areas[1]	Proposed Critical Areas	National Natural Landmarks[2]
BELTRAMI				
1.	Pennington Orchid Bog	x		
2.	Kitchi Lake Swamp	x		
3.	Big Bass Lake Swamp	x		
4.	Lake Bemidji State Park	x		x
5.	Upper Red Lake Peatlands	x	x	
6.	Peat Gasification Area-Minnegasco			
CASS				
7.	Little Portage Lake Swamp	x		
8.	Pike Bay Swamp	x		
9.	Boy River Orchid Bog	x		
10.	Project 80 (5-N15)		x	
CLEARWATER				
11.	Itasca Wilderness	x		x
12.	Iron Springs Bog	x	x	
13.	Marshall Bog	x		x
14.	Project 80 (2-N31)		x	
COOK				
15.	Hovland Woods	x		
HUBBARD				
16.	Badoura Bogs		x	
17.	Twin Lakes Bog			x
ITASCA				
18.	Sunken Lake Research Natural Area			x
KOOCHICHING				
19.	Lake Agassiz Peatlands Natural Area	x	x	x
20.	Lost River Peatlands	x		
21.	Tamarack River	x		
22.	North Black River Peatlands	x		
23.	Pine Island Bog	x	x	
24.	Caldwell Brook Cedar Swamp		x	
25.	Peat Bogs--Peatland Development		x	

Table 7. Areas of Special Concern in Northern Minnesota Peatlands (cont.).

County		Scientific and Natural Areas[1]	Proposed Critical Areas	National Natural Landmarks[2]
LAKE				
26.	Superior National Forest Bog	x		
27.	Silver Cliff, Lafayette Bluff and Encampment Forest	x		
28.	Sand Lake Bog	x		
29.	Weber Lake	x		
MARSHALL				
30.	Potential Peat Development Area and Buffer		x	
PINE				
31.	Lake Margaret Kerrick Bogs	x		
ROSEAU				
32.	Potential Peat Development Area and Buffer		x	
33.	Potential CuNi Development Area and Buffer		x	
ST. LOUIS				
34.	Slim Lake	x		
35.	Purvis Lake--Ober Foundation	x		

1 Includes areas proposed, being processed or accepted.

2 Includes landmark areas proposed or accepted.

Source: Minnesota State Planning Agency (1978).

FOREST RESOURCES OF MINNESOTA'S PEATLANDS

The first sections of this report reviewed the development and classification of peatlands and described plant species, communities, and areas of special concern. This section will describe the peatland forest resource and its current utilization.

Area and Location

Minnesota's 7.2 million acres of peatlands comprise approximately 14 percent of the State's 51.2 million acres of land (Midwest Research Inst. 1976). The peatlands of southern Minnesota are small, scattered, and generally nonforested. In contrast, the peatlands of northern Minnesota are often extensive and forested. Over half of the State's peatlands are located in eight northern counties (MLMIS). This section of the report will be concerned with peatlands in Aitkin, Beltrami, Carlton, Itasca, Koochiching, Lake of the Woods, and St. Louis Counties. Table 8 presents some statistics on the size of the peat resource in these counties. The variation in estimates of peatland acreages in Table 8 is indicative of the need for a more complete and accurate inventory.

Use Patterns

Table 9 lists various peatland uses in seven north-central counties and the entire State. Forest is the predominant cover on northern peatlands. In five of the seven counties listed in Table 9 over 75 percent of the peatlands are forested, while on a state-wide basis only 60.4 percent of the peatlands are forested. Forest uses account for only 49.8 percent

Table 8. Total Land Area and Peatland Acreage in Selected Minnesota Counties.

	Land Area[1]	Peatland[2]	Peatland[3]	Peatland[4]
Aitkin	1,167,400	398,300	--	393,466
Beltrami	1,610,900	[5]	--	785,661
Carlton	550,400	35,000	--	97,700
Itasca	1,704,300	250,000	--	356,588
Koochiching	2,002,600	1,000,000	986,120	1,154,899
Lake of the Woods	837,100	[5]	421,600	482,528
St. Louis	4,019,800	1,192,000	--	810,644

[1] From Stone (1966); Table 17.

[2] From Soper (1919); page 33. Includes areas with average peat depth over 5 feet.

[3] From MLMIS (Minnesota Land Management Information System).

[4] From Conservation Needs Inventory (1959) as reported in Midwest Research Inst. (1976). These estimates are based on statistical surveys and do not include federal non-crop land, urban areas, or Indian lands under trusteeship. Thus, these estimates are probably conservative.

[5] At the time of Soper's survey Beltrami County included what is now Lake of the Woods County. The total peatland area for Beltrami was given as 1,299,200 acres.

Table 9. Peatland Uses in Selected Minnesota Counties[1]

	Percent of Total Peatland Area in			
	Cropland	Pasture	Forest	Open
Aitkin	0.0	2.9	49.8	47.3
Beltrami	0.0	3.0	76.6	20.4
Carlton	0.0	4.6	86.6	8.8
Itasca	0.0	1.0	98.3	0.7
Koochiching	0.0	0.3	99.7	0.0
Lake of the Woods	2.5	1.2	36.5	59.8
St. Louis	0.0	0.2	84.2	15.6
State of Minnesota	2.7	10.7	60.4	26.2

[1] Based on Conservation Needs Inventory (1967) as reported in Midwest Research Inst. (1976); Table 5.5.

and 36.5 percent of the peatlands in Aitkin and Lake of the Woods counties, respectively. Large portions of the peatlands in these two counties are not forested. The open peatlands in Aitkin County are largely associated with the Glacial Lake Upham lacustrine plain, while those in Lake of the Woods County are on the Glacial Lake Agassiz plain. Pastur and cropland are relatively minor uses of the northern peatlands.

Table 9 indicates the relative frequency of occurrence of forests on peatlands, but it does not provide information on the quality or relative value of those forests. The various types of forests occurring on these northern Minnesota peatlands will be described next.

Peatland Forest Types

The seven north-central counties contain 8,013,000 acres of commercial forest land (see Table 10). The value of this commercial forest land depends in part on the species present and the inherent productivity of the site. A classification of peatland vegetation types was discussed in the first section of this report. For forestry purposes a forest cover type classification is often more useful. Forest cover types are characterized by the prevalence of one or more tree species. For example, a forest in which black spruce trees comprise a plurality of the stocking is classified as a black spruce type. Stocking is based on the area occupied by the present tree cover (Stone, 1966). The environmental factors which control the occurrence of plant communities also influence the distribution and productivity of forest types. Some peatland forest types and their corresponding vegetation types from Section I are listed in Table 11.

Table 10. Total Acreage, Forest Land, and Commercial Forest Land in Selected Minnesota Counties.

	All Land[1]	Forest Land[2]	Commercial Forest	
			Acreage	Percent
Aitkin	1,167,400	900,400	850,600	73
Beltrami	1,610,900	1,178,200	993,000	62
Carlton	550,400	334,400	310,700	56
Itasca	1,704,300	1,480,900	1,411,900	83
Koochiching	2,002,600	1,781,700	1,273,500	64
Lake of the Woods	837,100	623,400	528,500	63
St. Louis	4,019,800	3,226,700	2,644,800	66
State of Minnesota	51,205,800	19,047,400	17,062,000	33

[1] From Stone (1966); Table 17.

[2] For Aitkin, Beltrami, Itasca, and Lake of the Woods Counties and total State values are as of 1962 (Stone, 1966; Table 17). For Carlton, Koochiching, and St. Louis Counties values are for 1977 (North Central For. Exp. Station., unpublished).

Table 11. Similar Units in the "Forest Type" and "Vegetation Type" Classification Systems.

Forest Type[1]	Vegetation Type[2]
Black spruce	Swamp conifer: Spruce-feathermoss Swamp conifer: Spruce-sphagnum
Tamarack	Swamp conifer: Tamarack
Northern white-cedar	Swamp conifer: White-cedar
Lowland hardwoods	Swamp hardwoods
Lowland brush	Wooded fen
Lowland brush	Swamp shrubs

1 Forest Survey types (Stone, 1966).

2 Vegetation types after Fox et al. (1977) with some modifications.

Table 12. Commercial Peatland Forest Acreage by Forest Type in Selected Minnesota Counties.

	Black Spruce	Tamarack	White-cedar	Lowland Hardwoods	Total
Aitkin	49,200	59,300	9,900	148,700	267,100
Beltrami	58,400	88,200	43,100	88,500	278,200
Carlton	20,600	15,500	2,700	37,800	76,600
Itasca	105,800	51,500	47,300	120,000	324,600
Koochiching	285,900	73,100	152,500	87,700	599,200
Lake of the Woods	106,400	34,500	30,000	29,500	200,700
St. Louis	299,800[1]	67,200	65,500	86,800	519,300
Totals	926,100	389,300	351,300	599,000	2,265,700

1 Does not include 18,497 acres of upland black spruce type or 11,727 acres of mixed swamp conifer type located on the Superior National Forest in St. Louis County.

Table 13. Changes in Commercial Forest Acreages in Carlton, Koochiching, and St. Louis Counties, 1962 to 1977.[1]

County	Total Commercial 1962	Total Commercial 1977	Black Spruce 1962	Black Spruce 1977	Tamarack 1962	Tamarack 1977	White-Cedar 1962	White-Cedar 1977
Carlton	367,000	310,000	21,400	20,600	10,100	15,500	4,100	2,700
Koochiching	1,574,700	1,273,700	396,200	285,900	106,000	73,100	131,700	152,500
St. Louis	3,204,300	2,644,800	378,900	299,800	54,000	67,200	69,100	65,500
	1977 as percent of 1962							
Carlton	85		96		153		66	
Koochiching	81		72		69		116	
St. Louis	83		79		124		95	

[1] 1962 data from Stone (1966) and IRRR (1964). 1977 data from U.S. Forest Service, North Central Forest Experiment Station.

The major peatland forest types in north-central Minnesota are black spruce, tamarack, northern white-cedar, and lowland hardwoods. These types vary widely in forest productivity. Table 12 lists the acreages of each type in the seven study counties.

While the forest types listed in Table 12 comprise most of the commercial peatland forest resource, they are not the only types found on peatlands. The balsam fir type occurs on both mineral and peat soils. The lowland hardwood type also occurs on both types of soils and thus is probably not as common on peatlands as Table 12 suggests. The lowland brush type is found on some commercial sites where the stocking of trees has been reduced to less than 10 percent. In addition to the commercial acreages listed above, there are large areas of unproductive forest land.

Table 13 lists changes in commercial forest acreage in three northern counties during the 15 years from 1962 to 1977. In Koochiching County the area classed as black spruce in 1977 is 72 percent of its area in 1962. Reasons for this shrinkage are unclear.

Uses, Value, and Harvest

Information on the volume, growth rate, and properties of the various species is also important in determining the value of the peatland forest resource.

The degree of utilization of the various peatland species depends not only on the supply but also on the uses of the wood, stumpage prices, delivered prices, location of markets, and accessibility of the timber.

Black spruce is the most widely used peatland species. On peatland sites black spruce is a small tree, rarely attaining sawlog size (9.0" dbh). Thus black spruce is almost exclusively a pulpwood species in Minnesota. The long fibers and bleachability of black spruce make it a highly desirable species for use in the manufacture of high quality papers. Minor uses include poles, lumber, and Christmas trees.

Peatland tamarack is also a relatively small tree. Old growth trees have great durability and are used for fence posts and poles. The species is also used for pulp and there is minor local use for lumber. Northern white-cedar is used for fence posts, poles, siding, lumber, shakes, and paneling. Cedar heartwood is very resistant to decay making the species a desirable post material.

The major lowland hardwood species are black ash and American elm. Black ash is used for lumber, furniture, millwork, and crates. American elm is used for crates, furniture, flooring, timbers, veneer, and to a limited extent for pulp. Recent advances in pulp technology may increase the utilization of lowland hardwoods.

Of the peatland forest species, black spruce is by far the most important in terms of acreage, volume harvested, and economic value. Pulp mills are the major users of black spruce. The size, location, and pulping processes of these mills influence the utilization preferences for black spruce and other peatland species.

Minnesota has 12 operating pulp mills (Lockwood's 1978). Of these mills, 5 are groundwood mills, 3 use other mechanical pulping processes, 2 are

Table 14. Pulp Mills in Minnesota.

Name/Location	Wood Requirements [1]	Pulping Process
Nu-Ply Div. Bemidji	90 hwd. aspen	Mechanical (defibrated)
Northwest Paper Div. Cloquet	300 swd. 500 hwd.	Kraft
Superwood Corp. Duluth	325	Mechanical (defibrated)
Blandin Paper Co. Grand Rapids	2/	Groundwood- refiner
Blandin Paper Co. Grand Rapids	2/	Groundwood- stone
Boise Cascade Corp. International Falls	200 swd. 420 swd.	Kraft
Boise Cascade Corp. International Falls	2/	Groundwood- stone and refiner
Hennepin Paper Co. Little Falls	60 swd.	Groundwood- stone
St. Regis Paper Co. Sartell	100 swd. 20 hwd.	Groundwood- stone
Certain-Teed Corp. Shakopee	80 hwd. chips	Mechanical (defibrated)
Hoerner Waldorf Div. St. Paul	300 hwd.	Semi-chemical NSSC
Hoerner Waldorf Div. St. Paul	none	Deinking plant

[1] Average daily use in cords/day. hwd. = hardwoods; swd. = softwoods.

[2] Not available.

Source: Lockwood's (1978).

kraft mills, 1 is a semi-chemical mills, and 1 is a deinking plant. Table 14 provides additional information about Minnesota's pulpmills.

The groundwood mills are heavily dependent on softwoods, especially spruce and fir. The kraft mills and those using mechanical processes other than groundwood can utilize pine and hardwoods.

The pulp mills obtain their pulpwood supplies in several different ways. Some buy stumpage and then contract independent loggers to cut it for them. Others rely on stumpage purchased and cut by loggers and delivered to the mills. Boise Cascade maintains a company logging operation which supplies a portion of its pulpwood requirement. Timber brokers are also involved in the marketing of pulpwood.

The Blandin Paper Co., Boise Cascade Corp., Northwest Paper Division of Potlatch Corp., and St. Regis Paper Co. purchased stumpage on state lands during fiscal year 1976 (MN. DNR, 1976). The Blandin sales were in Itasca, Koochiching, St. Louis, and Lake counties. Balsam fir and black spruce were the major species involved. Smaller volumes of northern white-cedar and tamarack were also purchased. The Boise Cascade sales were located in St. Louis, Koochiching, and Itasca counties. The sales were largely of aspen, black spruce, and balsam fir pulpwood and northern white-cedar posts. There were only two sales to Potlatch Corporation in fiscal 1976. Both were in St. Louis County and consisted mainly of jack pine and aspen pulpwood. Three St. Regis divisions bought timber on state land in fiscal 1976. The Sartell Division of St. Regis Paper Company purchased black spruce pulpwood in St. Louis County, while the Rhinelander, Wisconsin

mill purchased tamarack pulpwood in Beltrami County. The Wheeler Division at Cass Lake bought pine stumpage in Lake of the Woods County.

According to U.S. Forest Service data for 1976 (Blyth and Hahn, 1977), 286,100 cords of spruce, balsam fir, and tamarack were harvested for pulp use in Minnesota. With minor exceptions this volume came from swamp forests. This represents 24 percent of the total of 1,208,800 cords of pulpwood of all species produced in Minnesota in 1976.

The non-pulpwood peatland forest products (sawtimber, posts, poles, etc.) are purchased by several different wood using industries. Small sawmills are widely distributed in north-central Minnesota. Some of the bottom land hardwoods are purchased as fuel for residential heating.

The sales of stumpage on state lands in Koochiching County were analyzed to determine the relative importance of various peatland forest products. The state owns 54 percent of all the land and 78 percent of the peatlands in Koochiching County (MLMIS). Thus the sales data should correctly reflect the relative amounts of peatland species sold, but it should not be used to compare the importance of peatland and upland species. The data indicate the estimated timber volume on the sale area, not the actual harvest during fiscal 1976. In practice, the volume harvested from an area usually exceeds the estimated volume. The fiscal year 1976 timber sales are summarized in Table 15.

Table 15. Summary of State Timber Sales by Species and Product for Fiscal 1976--Koochiching County,

Product species	Shortwood[1] cords	Sawtimber mbf	Poles pieces	Piling linear ft.	Christmas trees pieces
Black spruce	30,926	0.5	2,250		24,000
Tamarack	4,785	14	440		
N. white-cedar	4,582	3	1,014		
Btmland Hdwds.	56	353			
Ash species	166	1			
Elm	15	44			
Balsam fir	7,941	5.7		500	
Aspen	25,989	3.2			
Pine species	2,402	394.75	344		50
Balm of Gilead	2,394				
Wh. spruce	733	76.35		2,200	
Basswood		3			
Oak species	120				

[1] Includes pulpwood, posts, sawbolts, fuelwood, and miscellaneous products scaled in cords.

Source: Minnesota DNR (1976).

Pricing Practices

Since state lands are a major source of peatland forest products, it will be worthwhile to examine the state's marketing procedures. When an area is selected for harvest, the DNR estimates the volume of timber on the tract by species and product. The stumpage price of the timber is then determined. The base price varies by species and product. The base price is then adjusted to reflect such factors as the distance to markets, ease of harvest, and accessibility of the tract. Sales of less than $1500 can be made without competitive bidding. Larger sales are advertised and sold at auction.

Table 16. Stumpage and Delivered Prices for Selected Species and Products[1]

Species/Product	Blackduck Area Stumpage Price[2]	Delivered Price Range in Minnesota (cord)
Black spruce/pulpwood	$8/cord	$43.00 - $44.50
Tamarack/pulpwood	$3/cord	$28.50 - $31.00
Balsam fir/pulpwood	$4/cord	$28.00 - $33.00
N. white-cedar/bolts (6"+)	$4/cord	$27.00 - $45.00
Ash/sawlogs	$15/MBF	$60.00 - $90.00[3]
Elm/sawlogs	$15/MBF	$55.00 - $90.00[3]

1 From Minnesota DNR (1978).

2 Prices in effect since 7/1/76. Revised prices will be in effect after 7/1/78.

3 Sawlog prices vary with quality of product and location. High prices are generally from sawmills in southeastern Minnesota.

Table 16 gives the Minnesota DNR's base stumpage price for some peatland forest products in the Blackduck area. These prices have been in effect since July 1, 1976. The base price will be revised on July 1, 1978. A slight increase in stumpage prices is expected. The prices paid for various products delivered to Minnesota mills on July 1, 1977, are also listed in Table 16.

SUMMARY

Information on the vegetation was obtained from an extensive review of past studies of northern Minnesota peatlands. Most of the previous studies dealt with the ecological aspects of these areas. However, some studies also provided plant lists descriptive of the vegetational composition.

The development of peatland vegetation is strongly related to groundwater flow, groundwater level, and water chemistry. Based on these relationships, peatlands are divided into three broad physiognomic classes: bogs, fens, and swamps. Bogs are floristically and nutritionally the poorest followed by fens and swamps. The latter are often productive forests.

To emphasize the interrelationship between vegetation and environment, a brief discussion is included about hydrarch succession and paludification in northern Minnesota.

Information from the vegetation studies reviewed is organized in the framework of modified existing classification systems. The vegetation types are related to moisture and nutrient conditions in the edaphic field of northern Minnesota's peatlands (see Fig. 1). Plant lists of peatland study areas are used to characterize floristically each vegetation type. Plant lists from earlier studies are often incomplete, lacking species information, especially about grasses, sedges, mosses, and lichens.

Various classifications of rare, endangered and threatened plant species and their legal status are reviewed. Ten peatland species are

considered to be of special concern and are discussed in relation to habitat factors, associated species, and vegetation types. The reported locations are mapped.

The preservation of individual species and total plant communities is inseparable from habitat preservation. To preserve individual species, communities, or total landscapes as they exist, the maintenance of the governing environmental conditions is necessary.

Of special interest are areas interconnected with water flow forming continuous systems. String fen and bog or forested island and fen complexes are such systems, the preservation of which requires that large areas be set aside. Areas between upland forests and treeless sphagnum bogs very often include several transitional stages of peatland vegetation. To preserve the individual stages requires preservation of the whole system. Each vegetation type is unique and representatives should be preserved.

Proposed or existing Scientific and Natural Areas, Critical Areas, and National Natural Landmarks are listed and mapped for the northern Minnesota area involved.

The broad purpose of the forestry phase of this project has been to summarize information from various sources which would help assess the possible impact of development of northern Minnesota's peatlands on the forest resource and the economy it supports. Relevant information concerns peatland forest area, the tree species and forest types present, and the current industrial use of the forest resource.

Major sources of information are the forest inventory and survey data being compiled by the Division of Forestry in the Department of Natural Resources jointly with the U.S. Forest Service, North Central Forest Experiment Station. Unfortunately, information for some of the counties is not yet available. However, information is summarized for Aitkin, Beltrami, Carlton, Itasca, Koochiching, Lake of the Woods, and St. Louis counties.

Information has also been obtained from Iron Range Resources and Rehabilitation studies and reports for individual counties, from the Minnesota Land Management Information system, from a report by Midwest Research Institute, and from the major industrial users of northern Minnesota's forest resources.

Information reported documents the great importance of the peatland forest as the primary resource base for many of the northern counties. The peatland acreage is approximately a third of the total land area of the seven counties as reported by one source. However, there is great variation in estimates made in three reports reviewed, indicative of the need for more accurate basic information. In these counties over 60 percent of the total land area is forested. Most of this forest land is classified as commercial, based on the species present and inherent productivity of the site. Data from 1964 for some counties and 1977 for others show that there are slightly over 2¼ million acres of commercial peatland forest including softwoods (black spruce, tamarack, white-cedar) and miscellaneous hardwoods, mostly black ash. Black spruce and tamarack

are the major species, occupying over half of this area. Black spruce is the major species both as to abundance and income generated because its stumpage value is double that of other species.

Because 1977 inventory information is available for Koochiching County and because of the critical importance of the forest resource there, more detailed information is summarized for it in this report. According to the Conservation Needs Inventory, 1967 as reported by Midwest Research Institute (1976), about 99 percent of the county is forested. Of the total of 1,781,700 acres of forest, 64 percent is classed as commercial forest, of which over a half million acres are swamp conifers or lowland hardwoods. Black spruce is again the most important single species. Koochiching County forests are the main source of wood for the large Boise Cascade paper mill in International Falls as well as several other state and out-of-state mills. The state owns 78 percent of all the peatlands in that county, and a summary of state timber sales of various species for 1976 is given in Table 15.

The forest resource is the major basis for the economy of many northern Minnesota counties. In Koochiching County some 659,000 cords of spruce and tamarack were harvested in 1976. Stumpage sales on state land alone totaled 30,926 cords. At prevailing stumpage prices for 1976 this represents a return of over $5 million that year totally and approximately $250,000 return on state lands alone. In addition, add-on values from processing and selling the products far exceeds the stumpage returns.

There are 12 mills in Minnesota which process wood pulp for various kinds of paper and other wood fiber products. Their location, pulping process, and daily wood requirements are given in Table 14. These mills depend, with minor exception, on Minnesota forest resources. In addition, there is some shipment of Minnesota wood, especially the swamp species, to Wisconsin mills.

Black spruce, the major species on northern Minnesota peatlands, has technical properties which make it a choice species for some types of paper and pulping processes. As a result, at least four of the mills require large volumes of this species to keep producing the kinds and qualities of paper they manufacture. While other species can be used in certain types of pulping processes and for certain kinds of paper, black spruce continues to be a required species in high demand. Because of this, any major loss of productive spruce acreage is a matter of critical concern. Table 13 documents a significant reduction in spruce acreage from 1962 to 1977 in Koochiching County. The reasons for this are not clear. They may relate to inconsistencies in 1962 and 1977 survey procedures.

RECOMMENDATIONS

In view of the paucity of knowledge of the peatland flora, especially concerning the grasses, sedges, mosses, and lichens, we recommend that such studies be conducted by appropriate specialists.

To preserve rare, endangered, and other species of special interest it will be necessary to identify areas of sufficient size to protect the total habitats of these species. The complex vegetation patterns on some bogs and fens can be preserved only by protecting large areas including the entire water flow system.

We recommend that proposed Scientific and Natural Areas and other possible areas in the northern peatlands with unique features be included in the state system as soon as possible. The two National Natural Landmarks in the area give some protection to the string fen and bog complex they include. However expansion of their boundaries may be necessary.

In view of the critical importance of the peatland forest resource to the economy of northern Minnesota counties, we recommend that the current forest inventory of the counties involved be accelerated and intensified, if necessary, to provide information as a basis for estimates accurate on a county or smaller area basis.

It is also recommended that the specific Minnegasco area proposed for development be inventoried to enable more exactly an estimate of the resultant economic loss especially of black spruce growing stock. The losses involved should not be considered as only the loss of stumpage values. The add-on value from product manufacture and related activities have far greater economic impact.

It is also recommended that, to the extent any acreage of productive spruce forest is destroyed by harvesting the peat, the area be reforested to spruce to maintain at least the present level of growth of that important species. To further offset loss of growth of peatland species from possible development, it is also recommended that more intensive forestry practices be applied including conversion of some presently unproductive swamp shrub areas to black spruce.

A SELECTED BIBLIOGRAPHY

Averell, J. L. and P. C. McGrew. 1929. The reaction of swamp forests to drainage in northern Minnesota. Dept. of Drainage and Waters, State of Minnesota. 66 pp.

Ayensu, E. S. 1975. Endangered and threatened orchids of the United States. Amer. Orchid Soc. Bull. 44(5):384-394.

Backeus, I. 1972. Bog vegetation re-mapped after sixty years. OIKOS 23: 384-393.

Bakuzis, E. V. 1959. Synecological coordinates in forest classification and in reproduction studies. Ph.D. Thesis, University of Minnesota, St. Paul. 178 pp.

Bakuzis, E. V. 1967. Some characteristics of forest ecosystem space in Minnesota. Papers 14th Congr. Intern. Union Forest Res. Org., Munich, September, 1967. Vol. 2, p. 107-125.

Bay, R. R. 1967. Groundwater and vegetation in two peat bogs in northern Minnesota. Ecology 48: 308-310.

Blyth, J. E. and G. T. Hahn. 1977. Pulpwood production in the Lake States by county 1976. USDA For. Serv. Res. Note NC-223, 4 pp.

Boelter, D. H. 1964. Water storage characteristics of several peats in situ. Proc. Soil Sci. Soc. Amer. 28: 433-435.

Boelter, D. H. and E. S. Verry. 1977. Peatland and water in the northern Lake States. USDA For. Serv. Gen. Techn. Pep. NC-31. 22 pp.

Brown, J. M. 1971. Evapotranspiration from some bog vegetation. Ecol. Soc. Amer. Bull. 52(2): 39.

_____. 1973. Effect of overstory removal on production of shrubs and sedge in a northern Minnesota bog. Minn. Acad. Sci. J. 38(2,3): 96-97.

Buell, M. F. and W. A. Niering. 1953. Vegetation of a raised bog near Itasca Park, Minnesota. Bull. Torrey Bot. Club 80(2): 123-130.

Buell, M. R., H. F. Buell, and W. A. Reiners. 1968. Radial mat growth on Cedar Creek Bog, Minnesota Ecol. 49: 1198-1199.

Buell, M. F. and H. F. Buell. 1975. Moat bogs in the Itasca Park area, Minnesota. Bull. Torrey Bot. Blub 102(1): 6-9.

Case, F. W., Jr. 1964. Orchids of the western Great Lakes Region. Cranbrook Institute of Science, Bloomfield Hills, Michigan. 147 pp.

Christensen, E. M., J. J. Clausen, and J. T. Curtis. 1959. Phytosociology of the lowland forests of northern Wisconsin. Amer. Midl. Natur. 62: 232-247.

Clausen, J. J. 1957. A phytosociological ordination of the conifer swamps of Wisconsin. Ecology 38; 638-645.

Clymo, R. S. 1964. The origin of acidity in Sphagnum bogs. The Bryologist 67: 427-431.

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

Cooper, W. S. 1913. The climax forest of Isle Royale, Lake Superior and its development. III. Bot. Gaz. 55: 189-235.

Correll, D. S. 1950. Native orchids of North America north of Mexico. Chronica Botanica; Waltham, Mass.

Criech, E. 1968. USFS Memorandum; Chippewa National Forest; File No. 2360, July 15, 1968. (unpublished)

Dachnowski, A. P. 1924. The stratigraphic study of peat deposits. Soil Sci. 17: 107-133.

_____. 1925. Profiles of peatlands within limits of glacial lakes Agassiz and Wisconsin. Bot. Gaz. 80: 345-366.

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

Dean, J. L. 1971. Wetland forest communities of the eastern Boundary Waters Canoe Area. M.S. Thesis, Univ. Minnesota, St. Paul.

Drury, W. H., Jr. 1956. Bog flats and physiographic processes in the Upper Kuskokwim River region, Alaska. Contrib. Gray Herbarium, Harvard University (178), 130 pp.

Farnham, R. S. 1956. Classification of Minnesota peat. Univ. Minnesota. Dept. of Soils. Inst. Agr. Rept. 7. 23 pp.

Fernald, M. L. 1950. Gray's manual of botany. American Book Co., Chicago, Ill.

Finney, H. R. 1966. Some characteristics of four raised bogs in northern Minnesota. Ph.D. Thesis, Univ. Minnesota, St. Paul.

Fish and Wildlife Service, USDI. 1976. Endangered and threatened species; plants. Federal Register, V. 41, No. 117, June 16, 1976.

Fox, R., T. Malterer, and R. Zarth. 1977. Inventory of peat resources in Minnesota. A progress report, Minn. Dept. Nat. Res., Div. of Minerals, 36 pp.

Gates, F. C. 1942. The bogs of northern lower Michigan. Ecol. Monogr. 12(3): 213-254.

Griffin, K. O. 1973. Paleoecological aspects of Red Lake peatland, Beltrami County, Mn. Ph.D. Thesis, Univ. Minnesota, Minneapolis, 173 pp.

_____. 1975. Vegetation studies and modern pollen spectra from the Red Lake peatland, northern Minnesota. Ecology 56: 531-546.

Hansen, H. L., V. Kurmis, and C. K. Smith. 1973. Vegetation. pp. 1-163. (In) Resource Basic Inventory--Primary Development Areas, Voyageurs National Park, Minnesota. Part I--Ecosystem Analysis (L. C. Merriam, Project leader). College of Forestry, Univ. Minnesota, St. Paul.

Harris, S. W. and W. H. Marshall. 1963. Ecology of water level manipulations on a northern marsh. Ecology 44: 331-334.

Heinselman, M. L. 1963a. Understanding the ecological diversity of peatlands--a key to successful silviculture. Unpublished report, reprint file, Forestry Library, Univ. Minnesota, St. Paul.

_____. 1963b. Forest sites, bog processes, and peatland types in the glacial Lake Agassiz region, Minnesota. Ecol. Monogr. 33: 327-374.

_____. 1965. String bogs and other patterned organic terrain near Seney, Upper Michigan. Ecology 46: 185-188.

_____. 1970. Landscape evolution, peatland types and the environment in the Lake Agassiz Peatlands Natural Area. Minnesota. Ecol. Monogr. 40: 235-261.

Hofstetter, R. H. 1969. Floristic and ecological studies of wetlands in Minnesota. Ph.D. Thesis, Univ. Minnesota, Minneapolis. 224 pp.

Hustich, I. 1955. Forest-botanical notes from the Moose River area, Ontario, Canada. Acta Geogr. 13(2): 1-50.

Hustich, I. 1965. A black spruce feather moss forest in the interior of southern Quebec-Labrador peninsula. Acta Geogr. 18(6): 1-26.

Iron Range Resources and Rehabilitation Comm. (IRRR). 1964. Timber resources of Minnesota. A series of reports on the timber resources of Minnesota counties. IRRR, St. Paul, Minnesota.

Janssen, C. R. 1967. A floristic study of forests and bog vegetation, northwestern Minnesota. Ecology 48: 751-765.

_____. 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 level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49: 1661-1676.

Jeglum, J. K., A. N. Boissenneau, and V. F. Haavisto. 1974. Toward a wetland classification for Ontario. Can. For. Serv. Great Lakes For. Res. Centre, Inf. Rept. O-X-215.

Joyal, R. 1971. The Marshall Bog near Itasca Park, Minnesota. Mich. Bot. 10: 78-88.

Ketcheson, D. E. and J. K. Jeglum. 1972. Estimates of black spruce and peatland areas in Ontario. Can. For. Serv. Great Lakes For. Res. Centre, Inf. Rept. O-X-172. 29 pp.

Kratz, T. K. 1977. Advance reproduction of black spruce (Picea mariana (Mill.) B.S.P.) in the glacial Lake Agassiz region of Minnesota. M.S. Thesis, Univ. Minnesota, St. Paul. 88 pp.

Kurmis, V., L. C. Merriam, M. Grafstrom, and J. Kirwan. 1978. Primary plant communities, Voyageurs National Park, Minnesota. College of Forestry, Univ. Minnesota, Rept. 1. 181 pp.

Kurz, H. 1928. Influence of sphagnum and other mosses on bog reaction. Ecology 9: 56-69.

Lakela, O. 1965. A flora of northeastern Minnesota. Univ. Minnesota Press, Minneapolis. 541 pp.

Leisman, G. A. 1953. The rate of organic matter accumulation on the sedge mat zones of bogs in the Itasca State Park region of Minnesota. Ecology 34: 81-101.

Lockwood's. 1978. Lockwood's directory of the paper and allied trades; 102nd ed. Vance Publ. Corp., New York. 712 pp.

Luer, C. A. 1969. The genus Cypripedium in North America. Amer. Orchid Soc. Bull. 38: 903-908.

_____. 1975. The native orchids of the United States and Canada excluding Florida. The New York Botanical Garden.

Midwest Research Institute. 1976. Peat program Phase I. Environmental effects and preliminary technology assessment. Midwest Research Institute. Minnetonka, Minnesota. 122 pp. + appendices.

Minnesota Department of Natural Resources (MDNR). 1976. Alphabetical listing of state timber permits sold in fiscal 1976, statewide and by county. Unpublished computer printout. MDNR, St. Paul, Minnesota.

_____. 1978. Information on prices for stumpage and forest products in Minnesota. Personal communication, MDNR, St. Paul, Minnesota.

Minnesota Land Management Information System (MLMIS). Major peat resources of Minnesota. A series of maps and related text. Minn. State Planning Agency, St. Paul, Minnesota.

Minnesota State Planning Agency. 1978. Critical areas inventory committee data handbook. Minn. State Planning Agency, St. Paul, Minnesota.

Moore, P. D. and D. J. Bellamy. 1974. Peatlands. Springer-Verlag. New York. 221 pp.

Morley, T. 1972. Rare or endangered plants of Minnesota with the counties in which they have been found. Unpubl. Rept. Dept. of Botany, Univ. Minnesota, Minneapolis. 13 pp.

Morley, T. 1969. Spring flora of Minnesota. Univ. Minnesota Press, Minneapolis. 283 pp.

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

Moyle, J. B. 1973. Native Minnesota plants that are uncommon or of special interest and their habitats. Unpubl. Rept. Dept. of Natural Resources, St. Paul, Minnesota. 14 pp.

_____. 1975. The uncommon ones; animals and plants which merit special consideration and management. Minn. Dept. Nat. Res., St. Paul, Minn.

North Central Forest Experiment Station. 1977. Preliminary data from 1977 forest survey of Unit 1. Unpublished. USDA For. Serv. North Central For. Exp. Sta., St. Paul, Minnesota.

Osvald, H. 1970. Vegetation and stratigraphy of peatlands in North America. The Royal Society of Sciences of Uppsala, Sweden. 96 pp.

Ownbey, G. B. 1978. Species distribution maps of Minnesota. Dept. of Botany Herbarium, Univ. Minnesota, St. Paul.

Parker, G. R. and G. Schneider. 1974. Structure and edaphic factors of an alder swamp in northern Michigan. Can. J. For. Res. 4(4): 499-508.

Petraborg, W. H. 1969. Regeneration of white-cedar in northern swamps. The Minn. Acad. Sci. 36(1): 20-22.

Poore, M. E. D. 1956. The ecology of Woodwalton Fen. J. Ecol. 44: 455-492.

P'yavchenko, N. I. 1976. Interrelation of forest and bog. For the USDA For. Serv. and National Sci. Foundation. Amerind Publ. Co., New Delhi. 173 pp.

Radforth, N. W. and C. O. Brawner (eds.). 1977. Muskeg and the northern environment in Canada. Univ. Toronto Press, Toronto. 399 pp.

Rathban, W. B. 1972. A national orchid bog. Unpubl. report by Chairman, Conservation Committee of the Orchid Society of Minnesota.

Rigg, G. B. 1940. Comparison of the development of some sphagnum bogs of the Atlantic Coast, the Interior, and the Pacific Coast. Amer. J. Bot. 27: 1-14.

Rosendahl, C. O. 1955. Trees and shrubs of the Upper Midwest. Univ. Minnesota Press, Minneapolis. 411 pp.

Sarasto, J. 1968. On the classification of swamps drained for forestry in Finland. Trans. 2nd Int. Peat Congr. Leningrad 1963. Vol. 1, pp. 105-110 (R. A. Robertson, ed.) Dept. Agric. and Fisheries, Scotland, Edinburgh Vol 1.2, 1090 pp.

Sather, J. H. 1976. Proceedings of the national wetland classification and inventory workshop, Fish and Wildlife Service. U.S. Dept. of the Interior, Washington, D.C. 110 pp.

Sjors, H. 1959. Bogs and fens in the Hudson Bay lowlands. Arctic 12(1): 2-19.

_____. 1961. Surface patterns in boreal peatland. Endeavour 20: 217-224.

Smithsonian Institution. 1975. State lists of Endangered and Threatened species of the continental United States. (As proposed to the U.S. Congress). Federal Register, V. 40, No. 127, July 1, 1975.

Soper, E. K. 1919. The peat deposits of Minnesota. Univ. Minnesota Geol. Survey Bull. 16, Minneapolis. 261 pp.

Stanek, W. 1977. Classification of muskeg. pp. 31-62 (in) Muskeg and the northern environment in Canada. (N.W. Radford and C. O. Brawner eds.). Toronto Univ. Press. Toronto. 399 pp.

Stewart, G. 1925. Forest types of the northern swamps. J. For. 23: 160-172.

Stone, R. N. 1966. A third look at Minnesota's timber. USDA For. Serv., North Central For. Exp. Sta. Resource Bull. NC-1. 64 pp.

Stuckey, I. H. 1967. Environmental factors and the growth of native orchids. Amer. J. Bot. 52: 232-241.

Thompson, L. C. and H. M. Kulman. 1976. Vegetation of tamarack stands in north central Minnesota. Minn. For. Res. Notes No. 255. College of Forestry, Univ. Minnesota, St. Paul.

Transeau, E. N. 1903. On the geographic distribution and ecological relations of the bog plant societies of northern North America. Bot. Gaz. 36: 401-420.

Tuxen, R., A. Miyawaki, and K. Fujiwara. 1976. An expanded classification of Oxycocco-sphagnetea. (Trans. from German). Can. For. Serv. Environment Canada. Inf. Rep. FMR-X-89. 14 pp.

Vincent, A. B. 1964. Growth and numbers of speckled alder following logging of black spruce peatlands. For. Chron. 40: 514-518.

Waring, R. H. 1958. A preliminary classification of Minnesota into ecological forest areas. Unpubl. report, College of Forestry, Univ. Minnesota, St. Paul. 42 pp.

Walter, H. 1977. The oligotrophic peatlands of western Siberia--the largest peino-helobiome in the world. Vegetatio 34: 167-178.

Watt. R. F. and M. L. Heinselman. 1965. Foliar nitrogen and phosphorus level related to site quality in a northern Minnesota spruce bog. Ecology 46: 357-361.