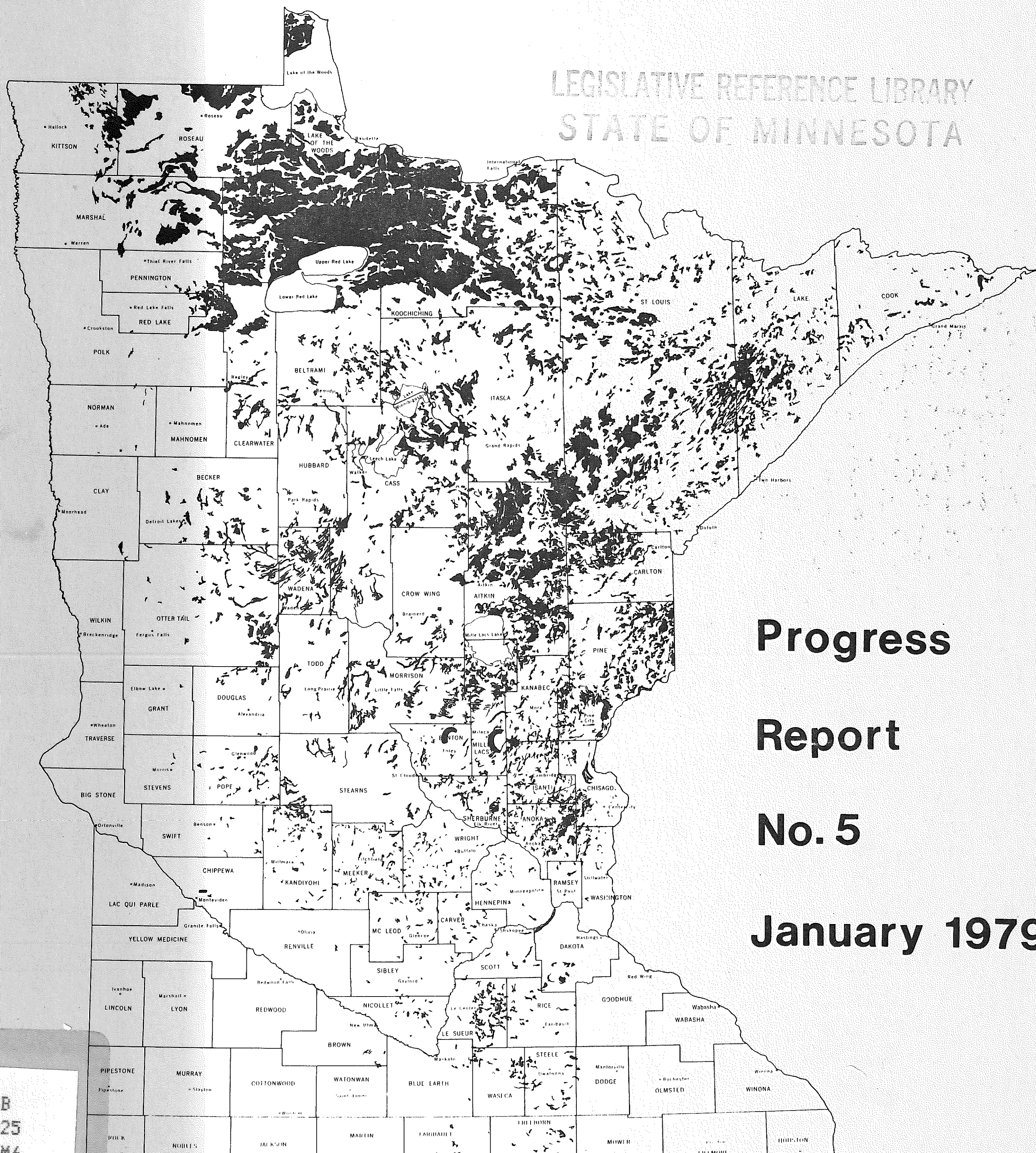
PEAT PROGRAM

1978-1979 BIENNIUM LEGISLATIVE APPROPRIATION



Progress Report No. 5

January 1979

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

MINNESOTA PEAT PROGRAM PROGRESS REPORT

JANUARY 1979

Submitted by the

Minnesota Department of Natural Resources

Funded by the

Minnesota State Legislature

(1978 - 1979 Biennium)

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PEAT PROGRAM PROGRESS REPORT

1978 - 1979 Biennium Legislative Appropriation

FOREWORD

The studies in this part of the Peat Program are complementary, as well as supplementary, to those funded by the Upper Great Lakes Regional Commission in the Phase II -- Peat Program.

These studies cover such areas as water resources of peatlands, the plants and animals of Minnesota peatlands, forest and agriculture reclamation of peatlands, and the analysis of Minnesota peat for possible industrial chemical uses. The results of these studies will provide information necessary for the formulation of a policy governing the management of state peatlands.

SECTION A

WATER RESOURCES OF PEATLAND

Progress Report No. 5

September 15 - December 15, 1978

This progress report is designed to provide a preliminary summary of the results of this research for presentation to the legislature.

Objectives:

To evaluate the effects of peatland development on water quantity.

To evaluate the effects of peatland development on water quality.

In order to achieve these objectives, four representative study areas were established in northern Minnesota each with a separate function (see Figure 1):

Corona Bog - horiticultural harvesting operation

Fens Bog - reclamation projects

Toivola Bog - natural peatland in NE Minnesota

Red Lake Bog - natural peatland in NW Minnesota

Each study area was instrumented for water budget analysis by measuring precipitation, runoff, evapotranspiration, and ground water levels. Water quality samples have been taken from the outflow points of these four study areas and analyzed for 30 water quality parameters as shown in Table 1.

FIGURE 1: LOCATION OF PEATLAND WATERSHED STUDY AREAS.

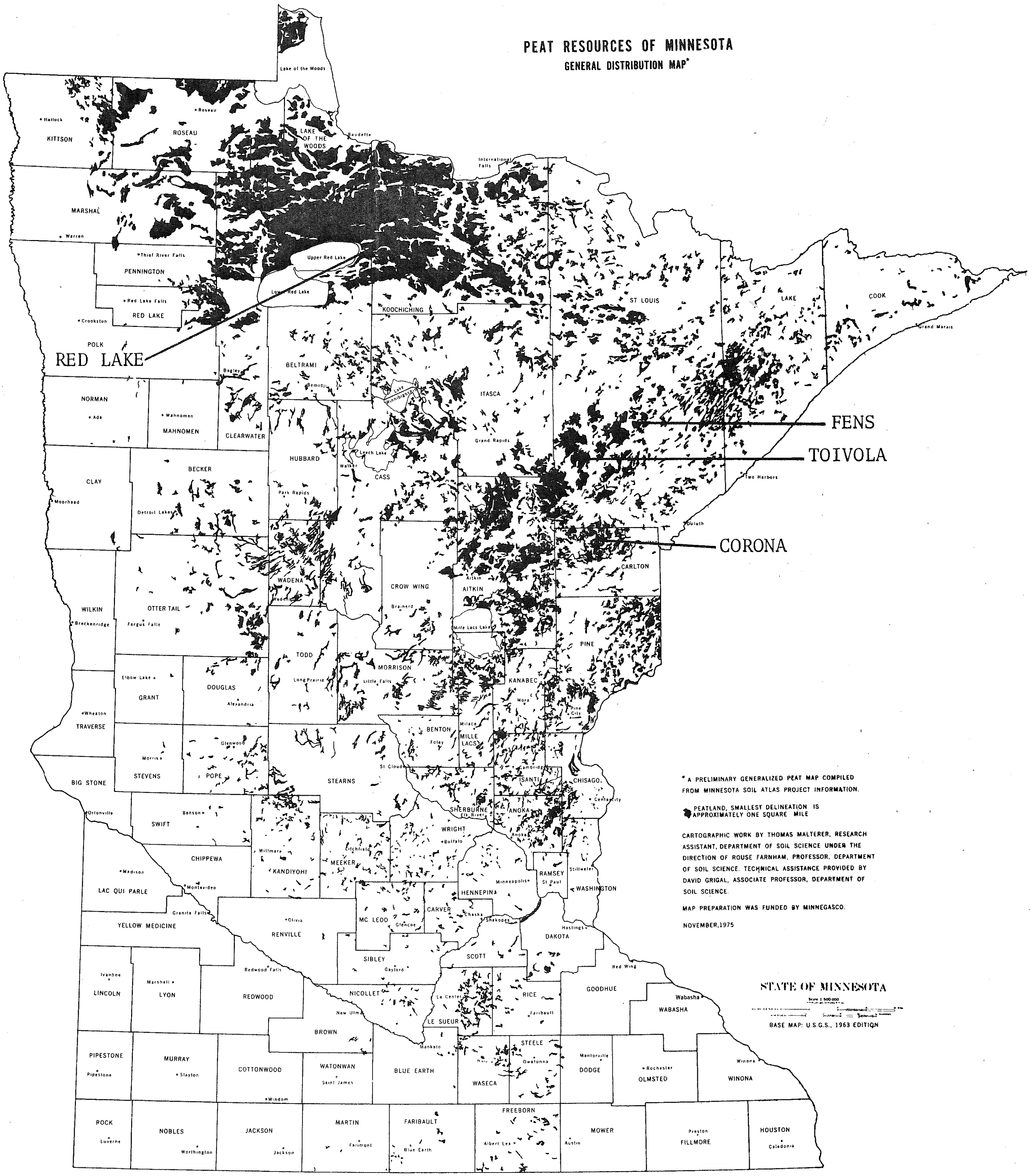

Table 1. Water Quality Parameters Collected From Northern Minnesota Peatlands.

temperature	total nitrogen	boron
dissolved oxygen	ammonia-N	lead
specific conductivity	nitrate + nitrite-N	nickel
pH	calcium	chromium
color	magnesium	cadmium
acidity	iron	cobalt
alkalinity	sodium	aluminum
suspended sediment	manganese	arsenic
volatile sediment	zinc	mercury
total phosphorous	copper	selenium

Preliminary Results

Water Quality

Table 2 contains a summary of some of the more important water quality values obtained to date. Streamflow from the two fen areas, Red Lake and Fens, is more basic and has a higher conductivity than that from the bogs, Corona and Toivola. These preliminary results also show that the two peatlands disturbed by ditching and cultivation or harvesting yield water of darker color, higher suspended sediment, and higher nitrogen and phosphorous than that from the undisturbed areas. Of additional interest is the results of heavy metal analysis shown in Table 3. These values are very low, near detection limits.

Table 2. Mean Water Quality Values for Select Peatlands in Northern Minnesota.

Parameter	Corona	Toivola	Red Lake	Fens
pH	5.1	5.9	7.0	6.5
Spec. cond. (umhos/cm)	67	47	113	207
Color (units)	390	250	190	540
Sus. Sediment (mg/l)	11.5	2.5	1.2	24.3
Total P (mg/l)	0.12	0.06	0.05	0.78
Total N (mg/l)	3.3	1.5	1.5	6.0
Means of 26 samples				

Table 3. Range in Values for Select Metals in Waters Leaving Peatland Study Areas.

Parameter	Range in Value
Mercury (ppb)	< 1.3 to 2.2
Selenium (ppb)	0 to 2.1
Arsenic (ppb)	0 to 5.3

Water Quantity

The existing literature on the effects of drainage on runoff from peatlands consists largely of studies in Europe. Most studies have concluded that drainage of peatlands reduces peak flows resulting from spring snowmelt or summer rainstorms, increases minimum flows over the rest of the year, and increases the total annual flow. Some studies have reported conflicting results.

A preliminary analysis has been made of the rainfall-runoff relationships for two of the study areas: Toivola and Corona. A one-inch rainfall on July 12 on both areas resulted in twice as much runoff from the undisturbed area (Toivola) as compared to the drained area (Corona). The run-off for this storm started almost immediately after the beginning of precipitation at Toivola while at Corona the runoff started about 3½ hours later. This single example supports the general conclusion found in the literature yet much more analysis is needed before this conclusion is certain.

Preliminary Conclusions

It is premature to develop conclusions from the information obtained to date. The effects of peat harvesting on water quality and quantity in Minnesota are not yet fully understood. However, the following are expressions of opinions on a preliminary basis:

1. It is felt that there exists a potential for peat harvesting operations to increase suspended sediments and nutrients, namely, nitrogen and phosphorous, in runoff waters.

2. Regarding water yield effects, it is felt that drainage may reduce peak flows if storage is sufficiently increased, and increase minimum and annual flows in evapotranspiration is sufficiently reduced.

Recommendations for Additional Research

By the end of the present study 1½ years of field data collection will have been completed. This amounts to one complete field season which was a wet year as compared to average conditions. In order to understand the complex hydrology and water quality questions associated with peat harvesting it is necessary to document whether the effects observed so far will occur again or occur under normal or dry conditions. Also, in order to adequately predict potential impacts, more than one years' data is needed.

Evaluation of reclamation studies, at Wilderness Valley Farms, from the hydrology and water quality point of view has not been accomplished since all plots have not been prepared to date. Therefore, it is proposed that monitoring alternative reclamation schemes be continued as they become available.

It is further proposed that the existing harvesting operation at Corona be investigated in a closer manner by monitoring the various aspects of harvesting peat including: bog preparation, newly harvested fields, older fields, and fields that are yet to be harvested. With this information the effect of various stages of peat development on water quality can be concluded.

In summary, it is proposed that this research be continued for an additional two years.

SECTION B

THE IMPORTANCE OF PEATLAND HABITATS
TO SMALL MAMMALS IN MINNESOTA

Progress Report
December 1978

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INTRODUCTION

The peatlands of Minnesota recently have received much attention from developers, scientists, and environmentalists with respect to their potential for utilization. Management decisions must consider the biological components of the peatlands and how they will be affected by disturbances. Small mammals are a part of the peatland fauna, but neither the status of individual species nor patterns of variation in composition of entire small mammal communities in the peatlands was known when this study began. Information regarding both the importance of small mammals to the peatlands and the importance of peatlands to small mammals is essential for making sound decisions concerning the future of peatlands in Minnesota.

The distributional status of most species of small mammals in Minnesota is reasonably well known overall (Gunderson and Beer, 1953; Heaney and Birney, 1975), and has been studied intensively in the extreme northeastern portion of the state (Timm 1975). A recent study of small mammal habitat types (Kalin 1976) provides general background information. Bog-dwelling species of small mammals have been studied in Michigan (Getz 1961a, 1961b), and in tamarack bogs of southern Manitoba (Buckner 1957, 1966). Essentially nothing is available on the importance of peatlands to mammals in Minnesota, and, unfortunately, the collecting techniques and analyses used by Kalin did not provide a complete list of bog-inhabiting species.

Six species of insectivores, *Condylura cristata*, *Sorex cinereus*, *S. arcticus*, *S. palustris*, *Microsorex hoyi*, and *Blarina brevicauda*, occur in moist habitats in Minnesota. Buckner (1966) found *S. cinereus*, *S. arcticus*, and *B. brevicauda* to be common in bogs in Manitoba. Two species of rodents, *Synaptomys cooperi* and *S. borealis*, have limited distributions in Minnesota, and usually are found in apparently disjunct populations in bog habitats. Several wide-spread species, especially *Microtus pennsylvanicus*, *Peromyscus leucopus*, and *Zapus hudsonius*, sometimes occur in high populations on peat habitats, but also are well known in adjacent habitats that provide adequate cover and nest sites. Two species of weasels, *Mustela erminea* and *M. nivalis*, are important predators of small mammals, and sometimes are common in wetland areas.

From this study, we hope to determine (1) which environmental factors have the greatest effect on the presence or absence of small mammals in peatland habitats, and (2) the degree to which individual species and entire communities are dependent upon peatlands. We will then be in a position to make predictions and recommendations regarding the type and degree of peatland development, at least as regards the effect of such perturbations on small mammals.

METHODS

A. State-wide survey

The state-wide survey of peatland small mammals was conducted in representative peatland habitats and adjacent non-peat habitats in selected regions throughout the state. For the survey, the state peatlands were divided into six regions (Fig. 1):

Northeastern region (Lake County)
North-central region (Koochiching County)
Northwestern region (Roseau County)
East-central region (Carlton County)
West-central region (Wadena County)
South-central region (Anoka and Chisago counties)

The survey was designed to provide: 1) baseline information concerning which small mammal species are associated with peatland habitats; 2) changes in small mammal species assemblages, both geographically and by habitat type; and 3) to identify any rare or regionally restricted species that occur in peatlands.

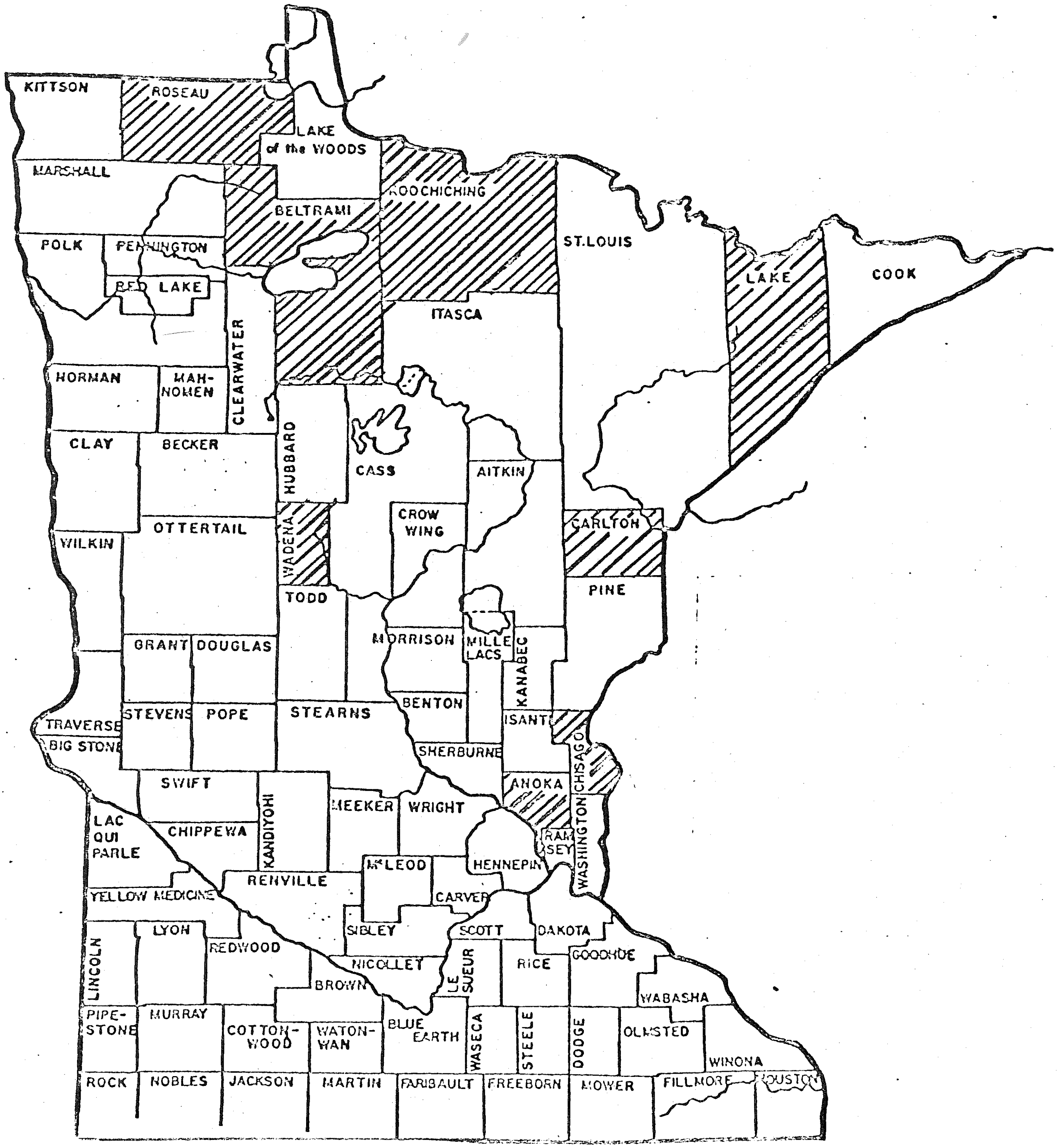

Figure 1: Location of survey sites.

The first survey was conducted from 31 August to 18 November 1977. A second survey, conducted from 26 June through 16 September 1978, involved retrapping exact sites sampled during the first survey. Repeition of the survey has strengthened our knowledge of the small mammals found in peatlands by: 1) providing additional distributional records; 2) indicating whether any major changes occurred in species distribution or abundance since the first survey; and 3) increasing the probability of capturing species missed during the first survey. The third point was particularly important with respect to hibernating species, which were largely absent from the first survey because of the late trapping dates.

Supplementary to the second survey, an additional trapping session was conducted in the Red Lake area in Beltrami and Koochiching counties. This investigation contributed information on small mammals to a bank of data gathered by other researchers at the same site. This survey was conducted from 28 September to 9 October 1978, and each trapping grid was sampled once.

Within each region, peatland habitats judged to be representative of the area were sampled together with one adjacent non-peat habitat. A maximum of 8 sites was trapped per region due to equipment and time limitations. However, 10 sites were trapped during the Red Lake survey. Table 1 gives the legal descriptions of the survey sites.

Several types of traps were employed in an attempt to mitigate the effect of differential trappability of the several species studied. Preliminary analysis of the trapping results confirms our initial hypothesis of strong, species-specific preference for different trap types among the small mammals captured. Traps used were Museum Special kill traps, Victor rat kill traps, Sherman live trap, cone pit-fall traps, and tube live traps. The tube traps did not work well and were not used after the first trapping session. At each trap site, a 2 by 20 or a 4 by 10 station grid was constructed with trap stations spaced 10m apart. One Sherman and one Museum Special were set at

Table 1: Legal descriptions of survey sites

Region 1: Lake County

Grid	
1-A	T60N, R11W, sec. 34, SW1/4
1-B	T59N, R11W, sec. 2, SW1/4
1-C	T59N, R11W, sec. 2, SW1/4
1-D	T59N, R11W, sec. 1, SW1/4
1-E	T61N, R10W, sec. 31, SW1/4
1-F	T61N, R11W, sec. 36, SE1/4
1-G	T61N, R11W, sec. 3, NW1/4
1-H	T61N, R11W, sec. 3, NW1/4

Region 2: Koochiching County

Grid	
2-A	T155N, R27W, sec. 21, NE1/4
2-B	T155N, R27W, sec. 22, NW1/4
2-C	T155N, R27W, sec. 10, SW1/4
2-D	T155N, R26W, sec. 21, SE1/4
2-E	T154N, R25W, sec. 33, SW1/4
2-F	T153N, R25W, sec. 4, NW1/4
2-G	T154N, R25W, sec. 33, SW1/4
2-H	T66N, R26W, sec. 26, NW1/4

Region 3: Roseau County

3-A	T163N, R39W, sec. 17, SW1/4
3-B	T163N, R39W, sec. 17, SW1/4
3-C	T163N, R40W, sec. 1, NW1/4
3-D	T163N, R40W, sec. 1, NW1/4
3-E	T164N, R40W, sec. 25, SW1/4
3-F	T164N, R40W, sec. 25, SW1/4
3-G	T164N, R37W, sec. 26, NE1/4

Region 4: Carlton County

4-A	T49N, R19W, sec. 18, NW1/4
4-B	T49N, R19W, sec. 18, NE1/4
4-C	T49N, R19W, sec. 16, NW1/4
4-D	T49N, R19W, sec. 22, SW1/4
4-E	T49N, R19W, sec. 22, SE1/4
4-F	T49N, R19W, sec. 34, SE1/4
4-G	T49N, R20W, sec. 1, NE1/4
4-H	T49N, R20W, sec. 28, NW1/4

Region 5: Wadena County

5-A	T136N, R33W, sec. 36, NW1/4
5-B	T138N, R33W, sec. 15, SE1/4
5-C	T136N, R33W, sec. 7, SE1/4
5-D	T136N, R33W, sec. 7, SE1/4
5-E	T136N, R33W, sec. 7, SE1/4

Region 6: Anoka and Chisago counties

6-A	T32N, R22W, sec. 19, NW1/4
6-B	T32N, R22W, sec. 7, SW1/4
6-C	T32N, R22W, sec. 18, NE1/4
6-D	T34N, R21W, sec. 26, NW1/4

Region 7: Red Lake (Beltrami and Koochiching cos.)

7-A	T156N, R29W, sec. 33, SW1/4
7-B	T155N, R29W, sec. 4, NW1/4
7-C	T155N, R29W, sec. 5, SE1/4
7-D	T155N, R29W, sec. 8, SE1/4
7-E	T155N, R29W, sec. 20, SE1/4
7-F	T156N, R30W, sec. 7, SW1/4
7-G	T156N, R30W, sec. 7, SW1/4
7-H	T156N, R30W, sec. 19, NW1/4
7-I	T156N, R30W, sec. 19, NW1/4
7-J	T155N, R31W, sec. 1, NE1/4

each station. Cone and rat traps were placed between trap rows at alternate stations (Fig. 2). Each trapping site was checked at dawn and at dusk for 4 consecutive days.

Habitat data were collected on each small mammal trapping grid. During the first survey, vegetation and peat information were gathered at two locations on each grid. Vegetational analysis was modeled after the releve' method of Braun-Blaunquet. The habitat was divided according to vegetation type, height class, and species present. Values for coverage, abundance, and sociability were assigned to the plantspecies. In addition, the percent cover of standing water, bare earth, and windfall and height of the hummocks were noted. Physical parameters were also recorded. These included depth of peat up to 160cm, temperature of peat at several depths, depth of water table, and pH of ground water. Peat samples were collected for later analysis for pH, water content, and peat classification. Change in the amount of standing water, bare earth, and windfall and any changes in the dominant vegetative cover were recorded by the second survey crew. In addition, new peat samples were taken at two depths (0-15cm and 15-30cm) for later laboratory analysis.

The small mammals collected during the two surveys were identified in the field and frozen for later analysis. Information currently being gathered from each specimen includes standard external measurements, age, sex, condition of pelage, and reproductive condition. Stomachs are being collected for later detailed analysis of food habits. Skins and skeletons of some specimens have been prepared for permanent preservation and availability as voucher specimens in the Bell Museum of Natural History, University of Minnesota. These include representative specimens of adult males and females of every species collected in a given region, as well as all specimens of the pygmy shrew (*Microsorex hoyi*), star-nosed mole (*Condylura cristata*), bog lemmings (*Synaptomys* spp.), meadow jumping mouse (*Zapus hudsonius*), woodland jumping mouse (*Napaeozapus insignis*), and ermine (*Mustela erminea*).

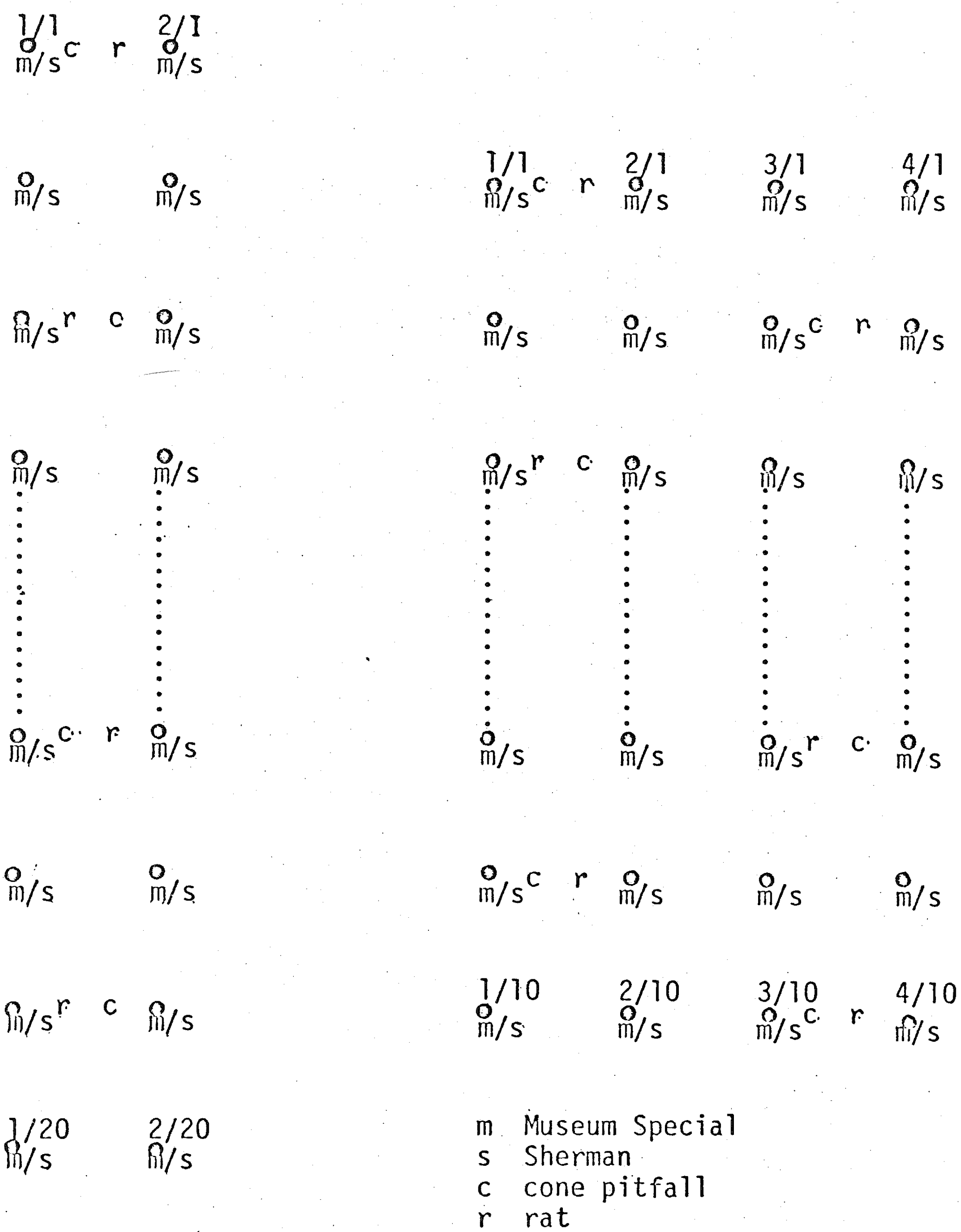

Figure 2. Diagram of trap placement for A) 2 by 20 station grid, and B) 4 by 10 station grid.

B. Intensive Study

The intensive study is exploring the temporal aspects of peatland small mammals, whereas the survey examined geographic and spatial aspects of the distribution and abundance. Small mammal populations in selected habitats within a single region are being monitored throughout the year. The emphasis of the study is to provide information concerning community structure and stability, and to determine the degree of dependence by small mammal populations on particular aspects of the peatland environment during their complete life cycle. Toward this end, population structure, local distributions, and habitat utilization of component species of small mammal communities are being examined; simultaneously, seasonal fluctuations in climate, vegetation, and the dietary items (i.e., sources of material found in stomachs of trapped animals) are being recorded.

The intensive study site was selected after careful study of maps of the state's peatlands, observations made during the first state-wide survey, and accessability to a maximum of "typical" peat types. The Big Falls area, including Koochiching and Pine Island State Forests, provides a variety of extensive peatland habitats, year-round accessability, and adequate lodging.

Following extensive reconnaissance of the area, 10 peatland sites representing the major peatland habitats of the region and 2 adjacent non-peat sites were selected. These sites are clustered into 4 groups of 3 adjacent habitats. In this way, comparative habitat preference among the small mammal species can be determined. Each of the 12 core sites will be monitored extensively throughout the year. Supplemental to the core sites, similar habitats in the region will be surveyed occasionally for comparison of local differences in small mammal communities with the core sites, based on differences in the adjacent habitats or disturbances to surrounding areas.

Figure 3 shows the location of the 4 core areas. Table 2 gives the legal description of these sites.

Within each site, separate areas have been established for trapping and for habitat analysis. We originally attempted to live-trap and mark individual animals within a single permanent grid in each site. Initial live-trapping results proved unrepresentative of the small mammals inhabiting the areas when compared to experimental grids consisting of 4 trap types set in the survey manner. Additionally, there was high mortality among the smaller shrews in the live traps. Based on these results, we have returned to the survey method of kill-trapping. This has necessitated a change in the sampling methods; instead of sampling a single grid repeatedly, a new grid is trapped during each sampling period. Each area trapped will be given at least 6 months for local populations to equilibriate before being retrapped. The trap grids are 4 by 10 stations each with 10m spacing between stations. The trapping grids within a single site are separated by a minimum of 20m. One Museum Special kill trap and one Sherman live trap are baited with peanut butter and oatmeal and set at each station. Traps are checked at dawn and dusk for 4 days; all sites within one area are sampled simultaneously. Supplemental trapping of similar habitats outside the core areas will be conducted in the same manner. Animals are identified in the field and held for later processing. Laboratory analysis of the specimens is the same as that for the state-wide survey.

During trapping periods, records are kept on weather conditions and physical parameters at the trap grids. These include amount of cloud cover, amount and type of precipitation, wind speed and direction, amount of snowfall, current air temperature and minimum and maximum temperatures for a 24 hour period at ground level and at 1m above ground, and soil temperatures at depths of 10cm, 30cm, and 60cm.

Figure 3. Location of core sites for the intensive study.

Table 2: Legal description of intensive study sites

Trap Sites	Location
1-A	T156N, R25W, sec. 12, SE1/4
1-B	T156N, R25W, sec. 12, SW1/4
1-C	T156N, R25W, sec. 12, SW1/4
2-A	T66N, R27W, sec. 12, NW1/4
2-B	T66N, R27W, sec. 11, N1/2
2-C	T66N, R27W, sec. 11, S1/2
3-A	T154N, R25W, sec. 15, NW1/4
3-B	T154N, R25W, sec. 15, NW1/4
3-C	T154N, R25W, sec. 10, SE1/4
4-A	T153N, R25W, sec. 3, SW1/4
4-B	T153N, R25W, sec. 3, NW1/4
4-C	T153N, R25W, sec. 3, NW1/4

Separate from the trapping grids, an area is reserved for habitat analysis and monitoring. Releves' of all sites have been completed. Additional vegetational analysis will continue throughout the study, including photopoint and phenological work. Peat samples are taken for further analysis, and water table fluctuations will be monitored. Additionally, periodic sampling of peat-dwelling invertebrates will be conducted along with collection of various plants to establish a reference collection for use in future food habit analysis.

RESULTS

A. State-wide Survey

All field data collection for the two surveys has been completed; small mammal species collected are listed in Table 3. These are based on field identification only, and positive identification is being done with laboratory analysis of the specimens. Designation of species for specimens of *Synaptomys* must await preparation and examination of skull characters. From the preliminary tabulations, however, up to 21 species of small mammals were collected. Two species, *Spermophilus tridecemlineatus* and *Napaeozapus insignis*, were never taken from peatlands and two species, *Condylura cristata* and *Synaptomys* sp., were never collected from non-peat areas. In addition to the specimens collected, sign was noted during the survey for the following species.

Geomys bursarius	Plains Pocket Gopher	non-peat only
Canis lupus	Gray Wolf	peat and non-peat
Ursus americanus	Black Bear	peat and non-peat
Odocoileus virginianus	White-tailed Deer	peat and non-peat
Alces alces	Moose	peat only

Small mammals associated with the various habitat types sampled are summarized in Table 4 for all regions surveyed, and presented by regions (7 regions) in Tables 5 to 11. Classification of habitat types is based on the designations of Fox et al. (1977).

Table 3. List of small mammals collected from the state survey

Species	Common Name
Sorex cinereus	Masked shrew
Sorex arcticus	Arctic shrew
Microsorex hoyi	Pygmy shrew
Blarina brevicauda	Short-tailed shrew
Condylura cristata	Star-nosed mole
Lepus americanus	Snoeshoe hare
Tamias striatus	Eastern chipmunk
Eutamias minimus	Least chipmunk
Spermophilus tridecemlineatus	Thirteen-lined ground squirrel
Spermophilus franklinii	Franklin's ground squirrel
Tamiasciurus hudsonicus	Red squirrel
Glaucomys sabrinus	Northern flying squirrel
Peromyscus maniculatus	Deer mouse
Peromyscus leucopus	White-footed mouse
Clethrionomys gapperi	Southern red-backed vole
Microtus pennsylvanicus	Meadow vole
Synaptomys spp.	Bog lemming (southern and/or northern)
Zapus hudsonius	Meadow jumping mouse
Napaeozapus insignis	Woodland jumping mouse
Mustela erminea	Ermine

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathemoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat: decid. fores	Non-peat: grassland
Sorex cinereus	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Sorex arcticus	X	X	X		X	X	X	X		X	X	X		X		X
Microsorex hoyi	X	X	X	X	X	X	X		X	X	X	X		X	X	
Blarina brevicauda	X	X	X	X	X	X	X	X		X	X	X		X	X	X
Condylura cristata			X									X				
Lepus americanus		X	X	X	X	X	X	X		X	X	X		X	X	
Tamias striatus		X			X					X				X	X	
Eutamias minimus		X										X		X	X	
Spermophilus tridecemlineatus															X	
Spermophilus franklinii		X		X											X	
Tamiasciurus hudsonicus			X		X	X	X	X		X	X	X		X	X	
Glaucomys sabrinus											X	X		X	X	
Peromyscus maniculatus			X	X	X	X	X			X	X	X		X	X	X
Peromyscus leucopus	X		X			X	X			X				X		X
Clethrionomys gapperi	X	X	X	X	X	X	X	X		X	X	X		X	X	X
Microtus pennsylvanicus	X	X	X	X	X	X		X							X	X
Synaptomys spp.	x	x		x	x		x	x		x	x	x				
Zapus hudsonius	x	x	x		x	x				x				x	x	x
Napeozapus insignis														X		
Mustela erminea		X	X		X						X	X			X	X

Table 4. Small mammals associated with peat and adjacent non-peat habitats in Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathemoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat decid. fores	Non-peat: grassland
Sorex cinereus	X	X			X			X		X	X			X		
Sorex arcticus	X	X			X			X			X					
Microsorex hoyi		X								X				X		
Blarina brevicauda	X	X						X		X				X		
Condylura cristata																
Lepus americanus								X		X	X					
Tamias striatus		X												X		
Eutamias minimus																
Spermophilus tridecemlineatus																
Spermophilus franklinii																
Tamiasciurus hudsonicus								X		X	X			X		
Glaucomys sabrinus																
Peromyscus maniculatus										X				X		
Peromyscus leucopus																
Clethrionomys gapperi	X	X			X			X		X	X			X		
Microtus pennsylvanicus	X	X			X			X								
Synaptomys spp.					X			X			X					
Zapus hudsonius	X				X											
Napeozapus insignis																
Mustela erminea																

Table 5. Small mammals associated with peat and adjacent non-peat habitats in Lake County, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat: decid. forest	Non-peat: grassland
Sorex cinereus	X				X		X			X	X	X			X	
Sorex arcticus							X					X				
Microsorex hoyi					X		X				X				X	
Blarina brevicauda					X						X	X			X	
Condylura cristata																
Lepus americanus					X		X			X	X	X			X	
Tamias striatus					X										X	
Eutamias minimus												X			X	
Spermophilus tridecemlineatus																
Spermophilus franklinii															X	
Tamiasciurus hudsonicus					X		X			X	X	X			X	
Glaucomys sabrinus															X	
Peromyscus maniculatus					X							X			X	
Peromyscus leucopus																
Clethrionomys gapperi	X				X		X			X	X	X			X	
Microtus pennsylvanicus																
Synaptomys spp.	X				X											
Zapus hudsonius	X														X	
Napeozapus insignis																
Mustela erminea					X							X			X	

Table 6. Small mammals associated with peat and adjacent non-peat habitats in Koochiching County, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat decid. forest	Non-peat: grassland
Sorex cinereus		X	X	X		X					X	X			X	
Sorex arcticus		X	X			X					X					
Microsorex hoyi		X		X		X					X	X			X	
Blarina brevicauda		X	X	X		X					X	X			X	
Condylura cristata												X				
Lepus americanus		X	X	X		X					X	X			X	
Tamias striatus															X	
Eutamias minimus		X													X	
Spermophilus tridecemlineatus															X	
Spermophilus franklinii		X														
Tamiasciurus hudsonicus						X					X	X			X	
Glaucomys sabrinus											X	X				
Peromyscus maniculatus						X					X	X			X	
Peromyscus leucopus																
Clethrionomys gapperi		X	X	X		X					X	X			X	
Microtus pennsylvanicus		X	X	X		X									X	
Synaptomys spp.				X												
Zapus hudsonius		X	X			X									X	
Napeozapus insignis																
Mustela erminea		X	X								X	X				

Table 7. Small mammals associated with peat and adjacent non-peat habitats in Roseau County, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat: decid. forest	Non-peat: grassland
Sorex cinereus			X	X			X	X		X		X		X		
Sorex arcticus			X											X		
Microsorex hoyi			X				X			X		X		X		
Blarina brevicauda			X				X			X		X		X		
Condylura cristata			X													
Lepus americanus			X					X		X		X		X		
Tamias striatus														X		
Eutamias minimus																
Spermophilus tridecemlineatus																
Spermophilus franklinii				X												
Tamiasciurus hudsonicus								X		X		X		X		
Glaucomys sabrinus																
Peromyscus maniculatus				X								X		X		
Peromyscus leucopus																
Clethrionomys gapperi			X	X			X	X		X		X		X		
Microtus pennsylvanicus			X	X												
Synaptomys spp.							X					X				
Zapus hudsonius										X				X		
Napeozapus insignis														X		
Mustela erminea			X													

Table 8 . Small mammals associated with peat and adjacent non-peat habitats in Carlton County, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat decid. forest	Non-peat: grassland
Sorex cinereus			X				X			X				X		
Sorex arcticus			X				X									
Microsorex hoyi			X				X			X						
Blarina brevicauda			X				X			X				X		
Condylura cristata																
Lepus americanus			X				X			X				X		
Tamias striatus										X				X		
Eutamias minimus														X		
Spermophilus tridecemlineatus																
Spermophilus franklinii																
Tamiasciurus hudsonicus										X				X		
Glaucomys sabrinus														X		
Peromyscus maniculatus			X											X		
Peromyscus leucopus			X				X			X				X		
Clethrionomys gapperi	X		X				X			X				X		
Microtus pennsylvanicus	X		X													
Synaptomys spp.										X						
Zapus hudsonius			X							X				X		
Napeozapus insignis																
Mustela erminea			X													

Table 9. Small mammals associated with peat and adjacent non-peat habitats in Wadena County, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathmoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat decid. forest	Non-peat: grassland
Sorex cinereus	X	X				X										X
Sorex arcticus	X	X														X
Microsorex hoyi	X	X														
Blarina brevicauda		X				X										X
Condylura cristata																
Lepus americanus						X										
Tamias striatus																
Eutamias minimus																
Spermophilus tridecemlineatus																
Spermophilus franklinii																
Tamiasciurus hudsonicus																
Glaucomys sabrinus																
Geomys bursarius																X
Peromyscus maniculatus						X										X
Peromyscus leucopus	X					X										X
Clethrionomys gapperi	X	X				X										X
Microtus pennsylvanicus	X	X				X										X
Synaptomys spp.																
Zapus hudsonius		X				X										X
Napeozapus insignis																
Mustela erminea																X

Table 10. Small mammals associated with peat and adjacent non-peat habitats in Anoka and Chisago counties, Minnesota.

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat: decid. forest	Non-peat: grassland
Sorex cinereus	X	X	X		X		X		X	X				X		
Sorex arcticus	X	X					X			X						
Microsorex hoyi							X		X	X						
Blarina brevicauda		X					X							X		
Condylura cristata																
Lepus americanus																
Tamias striatus														X		
Eutamias minimus																
Spermophilus tridecemlineatus																
Spermophilus franklinii																
Tamiasciurus hudsonicus			X											X		
Glaucomys sabrinus														X		
Peromyscus maniculatus							X							X		
Peromyscus leucopus																
Clethrionomys gapperi		X			X		X							X		
Microtus pennsylvanicus																
Synaptomys spp.		X														
Zapus hudsonius																
Napeozapus insignis																
Mustela erminea										X						

Table 11. Small mammals associated with peat and adjacent non-peat habitats in the Red Lake Bog Region (Beltrami and Koochiching counties, Minnesota).

A total of 2444 specimens was collected during the two surveys as a result of 34,320 trap-nights of effort. Table 12 summarizes the trapping results over all regions for the two years. Tables 13 to 19 provide trapping information based on field identification for each region.

Vegetational descriptions of the habitats sampled during the surveys are given in Tables 20 to 25. They provide a summary of the structure of the vegetation based on the relevés made in these habitats.

Tables 26-31 summarize the substrate data collected in the field, and the results of laboratory analysis of peat samples obtained during the first survey. Peat samples collected during the second survey await analysis.

B. Intensive Study

Data collection on this aspect of the small mammal study is in progress with results necessarily being preliminary and incomplete. Table 32 summarizes the small mammals collected from the core sites at this time. In addition to those captured, sign has been noted for the following species:

Castor canadensis	Beaver	peat and non-peat
Canis latrans	Coyote	non-peat only
Canis lupus	Gray wolf	peat and non-peat
Vulpes vulpes	Red fox	peat and non-peat
Ursus americanus	Black bear	peat and non-peat
Martes pennanti	Fisher	non-peat only
Mustela vison	Mink	peat only
Odocoileus virginianus	White-tailed deer	peat and non-peat
Alces alces	Moose	peat and non-peat

Sightings and sign of the above species were encountered opportunistically and thus are incomplete estimations of habitat utilization by them.

Table 33 describes the basic vegetative structure of the core habitats being sampled, based on the relevés. Peat samples from these sites await analysis.

Table 12. Summary of survey trapping for 1977 and 1978.

	1977	Grid	1978	Grid
Total capture (w/Red Lake)	1,593		721 (851)	
Total trap-nights	16,320		14,000 (18,000)	
Total species captured	18		20	
Site total: highest (peat) . . .	107	(3-C)	49	(4-H)
lowest (peat)		(2-G)	0	(2-B)
Site species richness: highest (peat)	9	(3-C)	9	(5-D)
lowest (peat)	2	(5-B)	0	(2-B)

SPECIES	TOTAL	TOTAL
Sorex cinereus	483	143 (221)
Sorex arcticus	83	54 (70)
Microsorex hoyi	41	14 (22)
Blarina brevicauda	66	53 (57)
Condylura cristata	1	1 (1)
Lepus americanus	9	26 (26)
Tamias striatus	3	29 (31)
Eutamias minimus	1	14 (14)
Spermophilus tridecemlineatus	-	2 (2)
Spermophilus franklinii	1	3 (3)
Tamiasciurus hudsonicus	7	5 (7)
Glaucomys sabrinus	4	3 (5)
Peromyscus maniculatus	68	59 (68)
Peromyscus leucopus	11	30 (30)
Clethrionomys gapperi	401	133 (140)
Microtus pennsylvanicus	396	61 (61)
Synaptomys spp.	8	6 (7)
Zapus hudsonius	3	52 (52)
Napaeozapus insignis	-	7 (7)
Mustela erminea	9	5 (6)

Table 13. Summary of survey trapping for Lake County, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	247		138	
Total trap-nights	3,520		3,200	
Total species captured	10		12	
Site total: highest (peat) . . .	83	(1-A)	35	(1-A)
lowest (peat)	13	(1-B)	9	(1-B)
non-peat	38	(1-C)	19	(1-C)
Site species richness: highest(peat)	7	(1-D)	7	(1-A)
lowest(peat)	5	(1-G)	2	(1-B)
non-peat	6	(1-C)	5	(1-C)

SPECIES	TOTAL	TOTAL
Sorex cinereus	100	14
Sorex arcticus	14	1
Microsorex hoyi	4	2
Blarina brevicauda	12	4
Condylura cristata	-	-
Lepus americanus	1	8
Tamias striatus	1	5
Eutamias minimus	-	-
Spermophilus tridecemlineatus	-	-
Spermophilus franklinii	-	-
Tamiasciurus hudsonicus	*	1
Glaucomys sabrinus	-	-
Peromyscus maniculatus	-	3
Peromyscus leucopus	-	-
Clethrionomys gapperi	72	62
Microtus pennsylvanicus	39	35
Synaptomys spp.	2	2
Zapus hudsonius	2	1
Napaeozapus insignis	-	-
Mustela erminea	-	-

* Present but not captured

Table 14. Summary of survey trapping for Koochiching County, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	181		75	
Total trap-nights	3,200		3,200	
Total species captured	10		12	
Site total: highest (peat)	43	(2-H)	15	(2-H)
lowest (peat)	3	(2-G)	0	(2-B)
non-peat	39	(2-E)	36	(2-E)
Site species richness: highest (peat)	8	(2-H)	7	(2-C)
lowest (peat)	3	(2-F)	0	(2-B)
non-peat	8	(2-E)	9	(2-E)

SPECIES CAPTURED	TOTAL	TOTAL
Sorex cinereus	85	6
Sorex arcticus	4	-
Microsorex hoyi	3	3
Blarina brevicauda	4	2
Condylura cristata	-	-
Lepus americanus	*	1
Tamias striatus	-	5
Eutamias minimus	-	2
Spermophilus tridecemlineatus	-	-
Spermophilus franklinii	-	2
Tamiasciurus hudsonicus	3	1
Glaucomys sabrinus	1	-
Peromyscus maniculatus	16	19
Peromyscus leucopus	-	-
Clethrionomys gapperi	58	10
Microtus pennsylvanicus	-	-
Synaptomys spp.	4	-
Zapus hudsonius	-	3
Napaeozapus insignis	-	-
Mustela erminea	3	;

* Present but not captured

Table 15. Summary of survey trapping for Roseau County, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	439		76	
Total trap-nights	2,800		2,800	
Total species captured	17		15	
Site total: highest (peat)	107	(3-C)	11	(3-F)
lowest (peat)	31	(3-G)	2	(3-G)
non-peat	35	(3-E)	34	(3-E)
Site species richness: highest (peat)	9	(3-C)	6	(3-A,B,C,F)
lowest (peat)	6	(3-G)	1	(3-G)
non-peat	10	(3-E)	9	(3-E)

SPECIES CAPTURED	TOTAL	TOTAL
Sorex cinereus	141	10
Sorex arcticus	27	3
Microsorex hoyi	17	3
Blarina brevicauda	25	1
Condylura cristata	1	-
Lepus americanus	1	6
Tamias striatus	2	8
Eutamias minimus	1	11
Spermophilus tridecemlineatus	-	2
Spermophilus franklinii	1	-
Tamiasciurus hudsonicus	1	2
Glaucomys sabrinus	3	2
Peromyscus maniculatus	8	13
Peromyscus leucopus	-	-
Clethrionomys gapperi	126	4
Microtus pennsylvanicus	76	2
Synaptomys spp.	2	-
Zapus hudsonius	11	8
Napaeozapus insignis	-	-
Mustela erminea	6	1

Table 16. Summary of survey trapping for Carlton County, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	254		180	
Total trap-nights	3,200		2,000	
Total species captured	9		16	
Site total: highest (peat)	72	(4-H)	49	(4-H)
lowest (peat)	8	(4-F)	4	(4-E)
non-peat	37	(4-C)	55	(4-C)
Site species richness: highest (peat)	7	(4-G,H)	6	(4-A,B,G,H)
lowest (peat)	3	(4-D)	3	(4-D,E,F,)
non-peat	7	(4-C)	11	(4-C)

SPECIES CAPTURED	TOTAL	TOTAL
Sorex cinereus	97	48
Sorex arcticus	22	28
Microsorex hoyi	8	4
Blarina brevicauda	9	14
Condylura cristata	-	1
Lepus americanus	5	9
Tamias striatus	-	5
Eutamias minimus	-	-
Spermophilus tridecemlineatus	-	-
Spermophilus franklinii	-	1
Tamiasciurus hudsonicus	2	1
Glaucomys sabrinus	-	-
Peromyscus maniculatus	27	18
Peromyscus leucopus	-	-
Clethrionomys gapperi	54	13
Microtus pennsylvanicus	30	17
Synaptomys spp.	-	3
Zapus hudsonius	-	10
Napaeozapus insignis	-	7
Mustela erminea	-	1

Table 17. Summary of survey trapping for Wadena County, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	126		170	
Total trap-nights	2,000		1,600	
Total species captured	9		15	
Site total: highest (peat) . . .	25	(5-A)	46	(5-E)
lowest (peat)	19	(f-D)	25	(5-A)
non-peat	41	(5-C)	64	(5-C)
Site species richness: highest (peat)	8	(5-D)	9	(5-D)
lowest (peat)	2	(5-B)	5	(5-E)
non-peat	6	(5-C)	11	(5-C)

SPECIES	TOTAL	TOTAL
Sorex cinereus	19	52
Sorex arcticus	4	11
Microsorex hoyi	6	2
Blarina brevicauda	15	22
Condylura cristata	-	-
Lepus americanus	2	2
Tamias striatus	-	6
Eutamias minimus	-	1
Spermophilus tridecemlineatus	-	-
Spermophilus franklinii	-	-
Tamiasciurus hudsonicus	*	*
Glaucomys sabrinus	-	1
Peromyscus maniculatus	11	6
Peromyscus leucopus	6	15
Clethrionomys gapperi	41	28
Microtus pennsylvanicus	22	3
Synaptomys spp.	-	1
Zapus hudsonius	-	19
Napaeozapus insignis	-	-
Mustela erminea	-	1

* Present but not captured

Table 18. Summary of survey trapping for Anoka and Chisago counties, Minnesota, 1977 and 1978.

	1977	Grid	1978	Grid
Total capture	346		82	
Total trap-nights	1,600		1,200	
Total species captured	8		8	
Site total: highest (peat)	71	(6-B)	40	(6-D)
lowest (peat)	38	(6-C)	17	(6-B)
non-peat	186	(6-A)	25	(6-A)
Site species richness: highest (peat)	7	(6-D)	6	(6-B,D)
lowest (peat)	5	(6-B)		
non-peat	5	(6-A)	7	(6-A)

SPECIES	TOTAL	TOTAL
Sorex cinereus	41	13
Sorex arcticus	12	12
Microsorex hoyi	2	-
Blarina brevicauda	1	10
Condylura cristata	-	-
Lepus americanus	*	-
Tamias striatus	-	-
Eutamias minimus	-	-
Spermophilus tridecemlineatus	-	-
Spermophilus franklinii	-	-
Tamiasciurus hudsonicus	-	-
Glaucomys sabrinus	-	-
Peromyscus maniculatus	6	-
Peromyscus leucopus	5	15
Clethrionomys gapperi	50	16
Microtus pennsylvanicus	229	4
Synaptomys spp.	-	-
Zapus hudsonius	-	11
Napaeozapus insignis	-	-
Mustela erminea	-	1

* Present but not captured

Table 19. Summary of survey trapping for the Red Lake Bog, Beltrami and Koochiching counties, Minnesota, 1978.

	1977	Grid	1978	Grid
Total capture	Not surveyed		130	
Total trap-nights			4,000	
Total species captured			11	
Site total: highest (peat)			25	(7-A)
lowest (peat)			6	(7-F)
non-peat			20	(7-D)
Site species richness: highest (peat)			6	(7-A)
lowest (peat)			1	(7-J)
non-peat			7	(7-D)

SPECIES	TOTAL	TOTAL
Sorex cinereus	Not surveyed	78
Sorex arcticus		16
Microsorex hoyi		8
Blarina brevicauda		4
Condylura cristata		-
Lepus americanus		-
Tamias striatus		2
Eutamias minimus		-
Spermophilus tridecemlineatus		-
Spermophilus franklinii		-
Tamiasciurus hudsonicus		2
Glaucomys sabrinus		2
Peromyscus maniculatus		9
Peromyscus leucopus		-
Clethrionomys gapperi		7
Microtus pennsylvanicus		-
Synaptomys spp.		1
Zapus hudsonius		-
Napaeozapus insignis		-
Mustela erminea		1

Table 20: Description of habitats for survey sites in Lake County, Minnesota.

Site	Classification	% cover <0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	hummock height(CM)
1-A	Swamp conifer: *Picea*, *Abies*	>75	>75	50-75	50-75	25-50	< 5	0	30-40
1-B	Open fen: *Chamaedaphne*, *Carex*	5-25	75	50-75	0	0	0	0	5-10
1-C	Non-peat: *Pinus*, *Betula*	50-75	25-50	50-75	50-75	<5	50-75	0	0
1-D	Swamp conifer: *Picea*, *Larix*	>75	25-50	50-75	25-50	0	0	0	40-50
1-E	Wood fen: *Salix*, *Myrica*, *Carex*	5-25	>75	25-50	0	0	0	0	10-15
1-F	Muskeg: *Picea*, *Larix*	>75	25-50	25-50	5-25	0	0	0	20-40
1-G	Swamp conifer: *Picea*, Feathermoss	>75	5-25	5-25	<5	25-50	0	0	40-50
1-H	Swamp conifer: *Picea*, *Larix*	>75	50-75	5-25	25-50	5-25	0	0	20-30

Table 21: Description of habitats for survey sites in Koochiching County, Minnesota.

Site	Classification	% cover							hummock height(CM)
		<0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	
2-A	Swamp conifer: *Picea*, feathermoss	>75	5-25	<5	<5	<5	50-75	0	20-30
2-B	Swamp conifer: *Picea*, Chamaedaphne	>75	50-75	25-50	5-25	25-50	5-25	0	40-50
2-C	Muskeg: *Picea*, *Larix*	<75	<75	5-25	25-50	<5	0	0	30-40
2-D	Swamp conifer: *Larix*, *Betula*, *pumila*	<75	<75	50-75	<5	5-25	25-50	0	40-50
2-E	Non-peat: *Populus*, *Alnus*	<75	<75	50-75	5-25	<5	50-75	0	-----
2-F	Muskeg: *Picea*, *Chamaedaphne*	<75	<75	5-25	5-25	0	0	0	60-70
2-G	Open bog: *Chamaedaphne*, *Carex*	<75	50-75	0	0	0	0	0	20-30
2-H	Swamp conifer: *Thuja*, *Abies*	<75	50-75	25-50	50-75	50-75	0	0	10-20

Table 22 : Description of habitats for survey sites in Roseau County, Minnesota.

Site	Classification	% cover							hummock
		<0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	height(CM)
3-A	Swamp conifer: Picea, Abies, feathermoss	<75	25-50	50-75	<5	25-50	50-75	0	40
3-B	Disturbed, drained wood fen: _Rubus_, Graminoids	25-50	<75	25-50	25-50	0	0	0	<10
3-C	Swamp conifer: _Larix_, Graminoids	25-50	50-75	>75	0	50-75	5-25	0	10-20
3-D	Swamp thicket: _Salix_, _Betula_	5-25	>75	>75	>75	0	0	0	<10
3-E	Non-peat: _Populus_, _Corylus_	50-75	50-75	>75	50-75	5-25	25-50	0	--
3-F	Swamp conifer: _Thusa_	>75	<5	<5	0	>75	<5	0	50-60
3-G	Open bog: _Ledum_, _Chamaedaphne_	>75	>75	5-25	0	0	0	0	50-60

Table 23: Description of habitats for survey sites in Carlton County, Minnesota.

Site	Classification	% cover							hummock
		<0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	height(CM)
4-A	Swamp conifer: _Thusa_, _Abies_	>75	50-75	5-25	<5	50-75	5-25	0	20-40
4-B	Swamp conifer: _Picea_, _Ledum_	>75	25-50	5-25	5-25	>75	0	0	30-40
4-C	Non-peat: _Abies_, _Corylus_	50-75	25-50	50-75	<5	5-25	50-75	0	---
4-D	Swamp conifer: _Larix_, _Ledum_	>75	>75	>75	0	0	50-75	0	30-40
4-E	Swamp conifer: _Picea_, _Larix_	>75	>75	25-50	25-50	25-50	0	0	30-40
4-F	Open bog: _Chamaedaphne_, _Ledum_	>75	>75	<5	<5	0	0	0	40-60
4-G	Swamp thicket: _Alnus_, _Betula_	>75	>75	<5	<5	0	0	0	20-30
4-H	Swamp thicket: _Salix_, _Spirea_	25-50	>75	>75	25-50	0	0	0	10

Table 24: Description of habitats for survey sites in Wadena County, Minnesota.

Site	Classification	% cover <0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	hummock height(CM)
5-A	Swamp conifer: Picea, Larix	>75	50-75	5-25	25-50	50-75	25-50	0	20-30
5-B	Open fen: Carex, Potentilla	25-50	>75	<5	0	0	0	0	10-20
5-C	Non-peat: Pinus, Quercus	5-25	50-75	50-75	<5	5-25	25-50	0	---
5-D	Swamp thicket: Betula, Alnus	25-50	50-75	>75	50-75	0	0	0	10-20
f-E	Swamp conifer: Larix, Alnus	>75	50-75	50-75	5-25	25-50	<5	0	20-30

Table 25: Description of habitats for survey sites in Anoka and Chisago counties, Minnesota.

Site	Classification	% cover <0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	hummock height(CM)
6-A	Non-peat: Graminoids	5-25	>75	5-25	0	0	0	0	---
6-B	Wood fen: *Salix*, *Spirea*	50-75	50-75	>75	5-25	0	0	0	10-15
6-C	Fen: *Typha*	<5	0	0	>75	0	0	0	<5
6-D	Swamp conifer: *Larix*, *Cornus*	50-75	25-50	>75	50-75	5-25	25-50	0	<20

Table 26. Peat description of habitats for survey sites in Lake County, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H20	Peat classification
1-A	S.C.: spruce/fir	Surface	100-160+	5.20 6.40	83.12 88.07	Sapric (live roots) Hemic
1-B	Open fen	Surface	>160	4.25 5.25	83.33 83.50	Fibric (reed/sedge) Hemic-Sapric
1-C	Non-peat: coniferous	---	---	5.90 4.94	44.12 55.21	Fine sandy loam
1-D	S.C.: spruce/tamarack	Surface	110-140	5.55 5.90	90.48 92.31	Hemic
1-E	Wood fen	Surface	>160	5.90 5.85	83.65 85.44	Sapric
1-F	Muskeg	Surface	>160	6.00 5.65	82.35 85.15	Hemic
1-G	S.C.: spruce/feathermoss	Surface	140	4.60 4.70	88.46 89.72	Hemic Hemic-Sapril
1-H	S.C.: spruce/tamarack	Surface	>160	5.20 4.80	86.79 89.62	Hemic

Table 27. Peat description of habitats for survey sites in Koochiching County, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H2O	Peat classification
2-A	S.C.: spruce/feathermoss	Subsurface	100-120	4.45 4.30	88.35 88.70	Hemic-Sapric
2-B	S.C.: spruce/	Subsurface	140-150	4.10 4.20	92.00 90.57	Fibric (Sphagnum) Hemic-Sapric
2-C	Muskeg	Surface	90-110	4.25 4.35	87.38 88.57	Hemic Hemic-Sapric
2-D	S.C.: Tamarack	Above Surface	110-140	5.20 5.40	89.62 91.67	Fibric (Sphagnum) Hemic
2-E	Non-peat: Deciduous	---	---	5.40 6.50	54.37 62.50	Sandy Loam
2-F	Muskeg	Surface	>160	4.15 4.20	89.42 92.31	Fibric (Sphagnum)
2-G	Open bog	Above Surface	70-80	4.30 4.50	93.27 93.58	Fibric (Sphagnum)
2-H	S.C.: Cedar, fir	Surface +	90-100	6.35 6.45	80.39 81.73	Sapric

Table 28. Peat description of habitats for survey sites in Roseau County, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H20	Peat classification
3-A	S.C.: spruce, feathermoss	---	100-130	5.30 5.50	77.23 78.43	Hemic Sapric
3-B	Disturbed wood fen	---	80-100	5.65 5.60	34.91 75.49	Sapric Hemic-Sapric
3-C	S.C.: Tamarack	---	70-90	5.80 5.25	74.04 70.48	Hemic
3-D	Swamp thicket	---	50	5.75 5.40	62.86 74.51	Hemic Fibric
3-E	Nonpeat: deciduous	---	---	5.65	36.79	Sandy loam
3-F	S.C.: cedar	---	90-115	5.60 6.45	80.99 75.49	Fibric
3-G	Open bog	Surface-Subsurface	50-80	4.70	87.83	Hemic-Sapric

Table 29. Peat description of habitats for survey sites in Carlton County, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H20	Peat classification
4-A	S.C.:cedar/fir	Subsurface	120	5.50 5.55	87.39 85.58	Hemic-Sapric Sapric
4-B	S.C.:spruce	Subsurface	120-160	4.85 5.05	90.27 88.29	Fibric Hemic
4-C	Non-peat:coniferous	---	---	5.25 5.10	20.51 25.49	Sandy loam
4-D	S.C.:Tamarack	Subsurface	>160	4.40 4.60	92.66 92.52	Fibric (Sphagnum)
4-E	S.C.:spruce/tamarack	Subsurface	>160	4.35 4.10	90.29 89.42	Fibric (Sphagnum)
4-F	Open bog	Subsurface	>160	4.60 4.40	87.26 87.50	Hemic-Sapric
4-G	Swamp thicket	Surface	100-160+	5.15	87.40	Hemic
4-H	Swamp thicket	Surface-above	120	5.80	75.00	Sapric (w/mineral)

Table 30. Peat description of habitats for survey sites in Wadena County, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H20	Peat classification
5-A	S.C.: spruce/tamarack	Subsurface	100-120	6.00 5.40	84.03 83.00	Hemic-Sapric Hemic
5-B	Open fen	Surface-above	90-100	5.55 5.35	84.76 85.05	Sapric (w/live roots)
5-C	Non-peat: mixed	---	---	5.20 5.05	26.79 35.16	Sandy loam
5-D	Swamp thicket	Subsurface-Surface	>160	5.60 5.30	83.48 83.17	Hemic-Sapric
5-E	S.C.: Tamarack	Surface-above	>160	5.95 5.80	83.48 87.39	Hemic

Table 31. Peat description of habitats for survey sites in Anoka and Chisago counties, Minnesota.

Site	Habitat classification	Water table(CM)	Peat depth(CM)	pH	% H20	Peat classification
6-A	Non-peat:grassland	---	---	4.95 5.75	19.64 19.05	Sandy loam
6-B	Wood fen	Above surface	>160	5.55 5.45	83.62 82.98	Hemic-sapric
6-C	Fen	Above surface	115-160+	5.75 5.20	84.81 84.11	Hemic
6-D	S.C.:tamarack	Surface-above	>160	6.20 6.65	78.51 82.20	Sapric

	Open fen	Wood fen	Swamp thicket	Open bog	Muskeg	Swamp conifer: open tamarack	Swamp conifer: closed tamarack	Swamp conifer: open blkspr/tam	Swamp conifer: open blk spruce	Swamp conifer: closed blk spruce	Swamp conifer: blkspr/feathermoss	Swamp conifer: Cedar		Non-peat: conif. forest	Non-peat: decid. forest	Non-peat: grassland
Sorex cinereus	X	X			X		X		X	X	X	X		X	X	
Sorex arcticus							X									
Microsorex hoyi																
Blarina brevicauda							X				X			X		
Condylura cristata																
Lepus americanus											X	X		X	X	
Tamias striatus																
Eutamias minimus																
Spermophilus tridecemlineatus																
Spermophilus franklinii																
Tamiasciurus hudsonicus					X		X		X	X	X	X		X	X	
Glaucomys sabrinus										X						
Peromyscus maniculatus											X	X		X	X	
Peromyscus leucopus																
Clethrionomys gapperi	X	X			X					X		X		X		
Microtus pennsylvanicus																
Synaptomys spp.																
Zapus hudsonius																
Napeozapus insignis																
Mustela erminea							X					X				

Table 32. Small mammals associated with peat and adjacent non-peat sites of the intensive study in Koochiching County, Minnesota.

Table 33: Description of habitats for survey sites in

Site	Classification	% cover <0.1m	0=5-0.1	1-0.5m	2-1m	5-2m	10-5m	>10m	hummock height(CM)
1-A	Swamp conifer: Picea, Larix	>75	>75	5-25	5-25	5-25	<5	0	
1-B	Swamp conifer: Picea, Abies	>75	>75	25-50	5-25	25-50	0	0	
1-C	Non-peat: Populus, Fraxinus	50-75	25-50	5-25	<5	5-25	>75	0	
2-A	Swamp conifer:Picea, Feathermoss	>75	25-50	5-25	<5	50-75	5-25	0	
2-B	Swamp conifer:Thusa, Abies	>75	25-50	25-50	5-25	>75	25-50	0	
2-C	Non-peat: Abies, Populus	50-75	>75	25-50	5-25	5-25	50-75	0	
3-A	Swamp conifer: Larix, Picea	>75	50-75	25-50	5-25	5-25	50-75	0	
3-B	Wood fen: Chamaedaphne, Ledum	>75	>75	25-50	<5	5-25	0	0	
3-C	Wood fen: Chamaedaphne, Betula	>75	50-75	25-50	0	0	0	0	
4-A	Swamp conifer:raised bog	>75	50-75	>75	5-25	25-50	0	0	
4-B	Muskeg: Picea, Ledum	>75	>75	5-25	<5	0	0	0	
4-C	Open fen: Carex, Equisetum	>75	50-75	>75	0	0	0	0	

DISCUSSION

The two surveys have provided valuable information concerning the small mammal species that live in the various peatland habitats of Minnesota. With this information we are now able to predict with reasonable accuracy the richness of small mammal communities, the relative abundance of the component species, and indicator species typcial of particular habitats. The second survey strengthened our data base from which these predictions can be made; but at the same time it produced results that differ significantly from those of the first survey. The trapping data from the second survey has only recently been compiled and has yet to be analyzed in detail. Discussions of the results, therefore, are preliminary statements about obvious trends. Any discussion of the magnitude of these trends or their significance to the overall picture of the ecology of peatland small mammals must await additional analyses of the material.

Conclusions that can be drawn at this time are: 1) the assemblages of small mammal species change with respect to the region of the state; 2) species richness and density vary according to habitat type; 3) species richness and density in a given habitat vary from year to year; and 4) the small mammal species show varying degrees of preference for or avoidance of peatland habitats. These conclusions are expanded below.

1) Regional differences. Distributional limits of individual species of small mammal and vegetational differences with respect to region appear to influence the composition of species that make up the small mammal communities found on peatlands in Minnesota. The structure of the vegetation and the plant species present can be correlated with the presence or absence of certain small mammal species. *Synaptomys*,

which was more commonly associated with open bog habitats, was not found in the southernmost sites that do not include habitat of this type. Peromyscus leucopus was not found at the northern sites, but was present in the southern sites. Sorex arcticus, which was often associated with grassy peatlands, was captured in greater numbers in the southern sites where grass is a more common component of the habitats.

The sites of the northwestern region were typically dry and the peat highly decomposed. This region was distinct in the occurrence of species typical of the prairie in peat habitats (Spermophilus spp.), and by having the greatest overall species richness and the greatest abundance of small mammals. The relative contribution by widely distributed species to the total catch of a region also varied across the state. In the northern sites, peatlands were overwhelmingly dominated by Sorex cinereus and Clethrionomys gapperi. In the southern sites, Microtus pennsylvanics and Peromyscus spp. generally dominated.

2) Habitat variation. As shown in the summaries of the trapping results, small mammal species richness, the density of individual species, and total number of small mammals varied dramatically between habitat types. Low richness and density were associated most often with low plant diversity, flooded conditions, and/or highly acid peatlands. High richness and density were associated with high plant diversity, drier peat, and/or more nutrient-rich peatlands. This trend was exhibited throughout the state. Habitats typically low in species richness and density were open bogs, flooded open fens, and black spruce/feathermoss forests. Habitats high in small mammal number and species richness were cedar swamps, drier tamarack swamps,

and swamp thickets. Non-peat sites were typically high in species richness, but not necessarily high in density. The structure of the habitats may also be important. Low richness-low density habitats were often open sites or forested habitats with sparse low-level vegetation. High richness-high density habitats were commonly typified by a dense shrub layer and/or significant amounts of windfall and exposed roots. This low cover may be critical in reducing the intensity of predation on small mammals by visually oriented predators.

3) Temporal variation. The total number of small mammals collected during the second survey was less than half that taken during the first survey. This trend was exhibited at most of the sites sampled. Trapping results from the intensive study support the hypothesis that small mammal population densities were significantly lower in 1978, and that this difference in trapping success was not due to the early trapping date of the second survey. Despite the lower catch, the second survey recorded two additional species (*Spermophilus tridecemlineatus* and *Napaeozapus insignis*) that were not captured during the first survey. The earlier trapping period of the second survey also enabled documentation of the presence of other hibernating species such as *Tamias striatus*, *Eutamias minimus*, and *Zapus hudsonius*, all of which were largely absent from the first survey.

Species richness was roughly similar for the two years; however, the assemblage of small mammal species and the relative contribution of each species to the total catch of a given site changed dramatically between years for many sites. For example, *Sorex cinereus* was the dominant species of peatland habitats in 1977, but was conspicuously low in the northern sites in 1978. *Clethrionomys gapperi* followed a similar but less pronounced trend. *Peromyscus* spp. and *Blarina brevicauda* were represented in greater numbers in the second survey. Site 6-A in Anoka County provides a striking example of the 2-year differences in species composition, richness, and individual density.

1977		1978	
159	*Microtus pennsylvanicus*	8	*Zapus hudsonius*
13	*Sorex cinereus*	7	*Sorex cinereus*
9	*Clethrionomys gapperi*	4	*Peromyscus leucopus*
5	*Peromyscus maniculatus*	2	*Sorex arcticus*
186	Total	2	*Blarina brevicauda*
		1	*Microtus pennsylvanicus*
		1	*Mustela erminea*
		25	Total

4) Differences associated with habitat preference. The small mammals collected from the survey sites have shown important differences in their specificity to certain habitat types. Species such as *Sorex cinereus*, *Microsorex hoyi*, and *Clethrionomys gapperi* are nearly ubiquitous in their distribution throughout the variety of peat and non-peat habitats sampled. This contrasts sharply with the status of *Condylura cristata*, *Synaptomys* spp., and *Napaeozapus insignis*, all of which appear highly restricted to the few types of habitats in which they are found. *Microtus pennsylvanicus* occurred in greatest numbers in open habitats, whereas *Glaucomys sabrinus* and *Tamiasciurus hudsonicus* were found only in forested habitats.

The relative abundance of the small mammal species collected also suggest preferred habitats. Except for *Blarina brevicauda*, shrew species were found in greater abundance in peatland habitats. *Sorex cinereus* occurred in highest relative abundance in the tamarack swamps while *Sorex arcticus* was most abundant in swamp thickets. *Microtus pennsylvanicus* was a major component of the wetter peatland sites, and showed a strong preference for fens. *Clethrionomys gapperi* was present in greatest relative abundance in forested peatland sites. Peromyscus spp. were more abundantly represented in non-peat habitats and drier, richer peat sites.

Seasonal differences in cover, vegetation, and flooding may modify the degree of preference shown for particular habitats by small mammals. We hope to gain insight into this aspect of habitat selection through the efforts invested in the intensive study.

SUGGESTIONS FOR FUTURE RESEARCH

Information gathered during this study will provide an accurate general picture of the small mammals found in peatlands throughout the state. For the first time, we are beginning to develop a "feel" for the role that peatlands play in the ecology of small mammals. However, this study represents only an initial examination. Additional research can contribute significantly to our knowledge of peatland small mammals.

The temporal component of peatland utilization by small mammals is particularly important. Repetition of the survey has illustrated clearly that significant seasonal and year-to-year variation exists among the small mammal populations. Although the intensive study will provide insight into the seasonal variation occurring among peatland small mammals for a given year, it will fail to provide insight into the year-to-year variability associated with these seasonal changes. An additional year of continuous population monitoring would provide a much stronger data base from which to make conclusions concerning the ecological relationship between small mammals and peatlands.

For the studies conducted to date to bear maximum fruit, it will be essential that they not be terminated at the end of one, two or even a few years. We really only begin to develop an adequate understanding of our environment only after long-term effort to observe relationships, conduct experiments to test the validity of hypothesized relationships, and continually monitor the effects of both natural and human-induced perturbations of the environment. However, to continue all types of ongoing studies both intensively and extensively becomes a prohibitive financial burden for society to bear. If we can learn enough about a relationship and the ranges of natural variation involving that relationship we can develop statistically sound predictive techniques wherein a few environmental parameters are actually measured and the rest are estimated with calculated confidence limits by such techniques as regression.

Because of the reasonably clear-cut relationships that we are documenting between small mammal species richness, composition, and habitat selection of particular species with respect to other parameters such as peat type, moisture conditions, and vegetative characteristics of the peatlands, we believe that small mammals may serve as excellent, easily-studied indicator species. Thus with minimal expense, the effects of development (e.g., draining, logging, or harvesting) of peatlands could be monitored by collecting data on small mammals together with crude measures of vegetation and pH. From such limited data gathered at expense far less than a total ecosystem approach study, we could make reliable predictions regarding the general "health" of the ecosystem. To accomplish this, it is essential to continue to monitor essential parameters in control areas and in a variety of developed areas. Such studies ideally should be continued even after developed areas are abandoned and either actively reclaimed for recreational and other purposes or left to repair themselves by natures slow process of succession.

In summary, we would judge it to verge on criminal myopia to invest thousands of taxpayer dollars into a 2 or 3 year study to collect baseline data and then fail to follow through with limited but carefully planned and thorough monitoring studies during and following any peatland development.

LITERATURE CITED

Buckner, C. H. 1957. Population studies on small mammals of southeastern Manitoba. J. Mammal., 38:87-97.

Buckner, C. H. 1966. Populations and ecological relationships of shrews in tamarack bogs of southeastern Manitoba. J. Mammal., 45:181-194.

Fox, R., T. Malterer, and R. Zarth. 1977. Inventory of peat resources in Minnesota. Department of Natural Resources, State of Minnesota, St. Paul. 36 pp.

Getz, L. L. 1961a. Factors influencing the local distribution of Microtus and Synaptomys in southern Michigan. Ecology, 42:110-119.

Getz, L. L. 1961b. Factors influencing the local distribution of shrews. Amer. Midland Nat., 65:67-88.

Gunderson, H. L., and J. R. Beer. 1953. The mammals of Minnesota. Occas. Papers Minnesota Mus. Nat. Hist., Univ. Minnesota, 6:1-190.

Heaney, L. R. and E. C. Birney. 1975. Comments on the distribution and natural history of some mammals in Minnesota. Canadian Field-Nat., 89:29-34.

Kalin, O. T. 1976. Distribution, relative abundance, and species richness of small mammals in Minnesota, with an analysis of some structural characteristics of habitats as factors influencing species richness. Unpubl. Ph.D. Thesis, Univ. Minnesota, 160 pp.

Timm, R. M. 1975. Distribution, natural history, and parasites of mammals of Cook County, Minnesota. Occas. Papers, Bell Mus. Nat. Hist., Univ. Minnesota, 14:1-56.

SECTION C

Bird Populations and Habitat
Use in Minnesota Peatlands

Progress Report
December, 1978

for

Minerals Division
Minnesota Department of Natural Resources
Centennial Building
St. Paul, Minnesota

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General Area and Study Introduction

This study is designed to obtain quantitative data on the population structure of bird species that utilize resources of the several vegetation types growing on major peat deposits in Minnesota. The primary objective is to establish a firm base for predicting levels of impact on the bird species resulting from any degree of peat land development by man.

The Red Lake peatlands comprise 300 square miles of continuous bog north of Upper Red Lake in Beltrami, Lake of The Woods, and Koochiching Counties. Our study base was in Waskish, Minnesota, on the east shore of Upper Red Lake at the mouth of the Tamarac River.

This study has thus far been limited to the peatlands and adjacent uplands of Beltrami County, with the exception of one transect which was in Lake of the Woods County, 3 miles from the Beltrami County line. Within this area the following tasks have been undertaken: road censuses of woodcock, owls, and sharp-tailed grouse; location of booming grounds and broods of grouse; transect censuses of birds; transect vegetation measurements and descriptions (foliage density, foliage height diversity, plant relevés, and tree counts); and bird netting and banding as well as territory observations and nest location. The schedule of these activities throughout the 1978 field season was:

APRIL	MAY	JUNE	JULY	AUGUST	SEPT. 15

transect establishment---------

netting plot establishment-----

woodcock, grouse,
owl censusing------------------

insect collecting, keying---------------------------------------

Transect censusing---

Netting/bird banding---

Foliage density,
diversity-----------

Tree, shrub counts----

Data
compil-
ation

-------------------------Special Study: Spruce Island/Palm Warbler---

Bird Census Transect Description

Transect Number	Vegetation Type *	Legal Description	# of Censuses	# Bird Species Detected
MP1	Shrub Fen	Sec. 13, T156N, R31W	20	13
MP2	Shrub Fen	Sec. 13, T156N, R31W	20	11
MP3	Open Fen	Sec. 18, T156N, R30W	21	26
MP4	Open Fen	Sec. 18, T156N, R30W	20	17
MP5	Muskeg	Sec. 1, T155N, R31W	20	9
MP6	Muskeg	Sec. 1, T155N, R31W	20	10
MP7	Open Bog	Sec. 11&12,T155N,R31W	22	8
MP8	Open Bog	Sec. 11&12,T155N,R31W	22	5
MP9	Swamp Conifer-Spruce	Sec. 6, T155N, R30W	21	15
MP10	Swamp Conifer-Spruce	Sec. 6, T155N, R30W	21	15
MP11	Swamp Conifer-Spruce	Sec. 6, T155N, R30W	20	17
MP12	Poor Swamp Forest	Sec. 18, T155N, R30W	21	22
MP13	Poor Swamp Forest	Sec. 7, T155N, R30W	20	17
MP14	Swamp Thicket	Sec. 19, T155N, R30W	20	44
MP15	Swamp Thicket	Sec. 24, T155N, R31W	20	36
MP16	Swamp Conifer-Tamarack	Sec.16&19,T154N,R30W	19	34
MP17	Sw.Con.-Spruce Featherm.	Sec.9&10,T154N, R30W	19	32
MP18	Sw.Con.-Spruce Featherm.	Sec. 20, T154N, R30W	16	26
MP19	Sw.Con.-Cedar-Spruce	Sec. 32, T154N, R30W	22	33
MP20	Sw.Con.-Cedar-Spruce	Sec.32&29,T154N,R30W	22	38
MP21	Sw.Con.-Cedar-Spruce	Sec. 29, T154N, R30W	22	40
MP22	Mix.Con-decid. Upland	Sec. 33, T154N, R30W	19	38
MP23	Mix.Con-decid. Upland	Sec. 33, T154N, R30W	20	32
MP24	Swamp Conifer-Tamarack	Sec.27&34, T153N,R30W	18	19
MP25	Conifer-Spruce Clearcut swamp	Sec. 9, T154N, R30W	18	30
MP26	Riparian Hardwood	Sec. 9,16,17 T157N,R32W	7	23
MP27	Riparian Hardwood	Sec. 9,16,17 T157N,R32W	7	27

* Names adapted from Fox, et al. 1977; Heinselman, 1970; Jeglum, et al., 1974.

In order to facilitate study of the avian species communities in the Upper Red Lake peatlands, vegetation types as described by Fox et al., 1977; Heinselman, 1970; Jeglum et al., 1974 were chosen first by aerial photographs and later investigated on foot. Air photo coverage, road and trail accessibility, and recommendations from area forester Roger Anderson and assistant forester Lyle Fenske were considered in overall habitat selection. Thirteen different habitat types were then chosen for their homogeneity, and within these a total of 27 line transects were established.

Since information regarding the birds we have studied will always be in context of which habitat-type they occurred in, a brief description of each and its title follows. Wherever possible the name we have assigned to a transect and its description is borrowed from descriptions given by Fox et al. (1977), Heinselman (1970), and Jeglum et al. (1974).

MP 1 & 2 Shrub Fen (Jeglum et al., 1974) "Low shrub Fen"

Dominant plant species including low shrub layer of bog birch (Betula glandulosa var. glandulifera = Betula pumila), leatherleaf (Chamaedaphne calyculata), buckbean (Menyanthes trifoliata), and sedges (including Carex rostrata). This is a relatively dry fen (on the downstream side of Hwy. 72) of interspersed low shrubs and open sedges.

MP 3 & 4 Open Fen (Fox et al., 1977; Jeglum et al., 1974)

Graminoid (grasses, sedges) cover greater than 75 per cent, and Sphagnum less than 50 per cent. Tree cover less than 5 per cent with few if any shrubs. Low nutrient availability and water table is at ground surface, such that sedges often form a floating mat. Dominant species include: Carex flava, C. lasiocarpa, Utricularia intermedia, Drosera intermedia, Pogonia ophioglossoides.

MP 5 & 6 Muskeg (Fox et al., 1977)

Bog with 5-25 per cent tree cover, mostly stunted black spruce. Sphagnum comprising essentially 100 per cent of floor cover. Dominant species include: black spruce (Picea mariana), Ledum groenlandicum, Sphagnum.

No transect. Black Spruce Ovoid Island

Although no transect was established in this island, this is the location of Bruce Fall's Palm Warbler study and we netted extensively in this area. The vegetation pattern within this "island" is similar to that described for muskeg, the trees being small as a result of fire forty years ago. Spruce islands commonly occur throughout the open fen.

MP 7 & 8 Open Bog (Fox et al., 1974; Jeglum et al., 1977)
Vigorous Sphagnum moss comprises over 75 per cent of the cover, tree cover less than 5 per cent. Jeglum et al. name the following Sphagnum species as dominants: *Sphagnum cuspidatum*, *S. fallax*, *S. magellanicum*, *S. pallustre*, and *S. rubellum*. Our transects also had many skeletons of dead trees scattered throughout. The open bog we studied is about 1.5 sq miles in area and is bordered by black spruce muskeg.

MP 9, 10, & 11 Swamp Conifer-Spruce (Fox et al., 1977; Jeglum et al., 1974)
Tree cover greater than 25 per cent, 75 per cent of which are black spruce. This is a wet hummocky area, dominant herbaceous plants include : Labrador tea (*Ledum groenlandicum*), bog rosemary (*Andromeda glaucophylla*), bog laurel (*Kalmia polifolia*), cranberry (*Vaccinium oxycoccos*), and leatherleaf (*Chamaedaphne calyculata*). A net plot was included in this habitat, but nets were taken down in June because of lack of netting success.

MP 12, 13 Poor Swamp Forest (Heinselman, 1970) "Stunted Tamarack"
Tree cover is similar to Swamp Conifer-Spruce, but dominated by stunted tamarack (*Larix laricina*). This is also covered with vigorous Sphagnum hummocks and a dense ericaceous layer. This habitat type lies adjacent to and intergrades with Swamp Conifer-Spruce.

MP 19, 24 Swamp Thicket (Fox et al., 1977: Jeglum et al., 1974)
Less than 50 per cent tree cover, but densely covered with tall deciduous shrubs, such as bog birch (*Betula pumila*), willows (*Salix sp.*), and alder (*Alnus rugosa*). A rich herbaceous layer was also present. We plan to establish a net plot in this area in April, 1979.

MP 16,24 Swamp Conifer-Tamarack (Fox et al., 1977)
Very wet with a relatively dense understory of shrubs including bog birch, buckthorn (*Rhamnus alnifolia*), dogwood (*Cornus stolonifera*), and willow (*Salix sp.*). Tree cover over 25 per cent, most of which is tamarack. A net plot was located within this habitat.

MP 17, 18 Swamp Conifer--Spruce, Feathermoss (Fox et al., 1977)
Forest of tall black spruce creating a fairly dense canopy. Understory is open, with the exception of widely scattered groups of shrubs. Floor is covered with vigorous Sphagnum and feathermosses.

MP 19, 20, 21 Swamp Conifer: Cedar-Spruce (Fox et al., 1977)
Comprised mostly of white cedar (*Thuja occidentalis*), forming a dense canopy, with frequently occurring small balsam fir trees (*Abies balsamea*). Herb layer is sparse where most densely shaded. A net plot was also included in the cedar forest.

MP 22, 23 Mixed Conifer-Deciduous Upland

This dry upland site is not a bog-vegetation type, but an example of one of the more elevated habitats found to the south of Waskish. Tree species are dominated by Quaking Aspen (Populus tremuloides) and balsam fir (Abies balsamea). Sphagnum is not present, but instead there is a vigorous shrub (hazel, bush honeysuckle, alder) and herb layer.

MP 25 Clearcut Swamp Conifer Spruce

This is a recently clearcut area, immediately adjacent to the Swamp Conifer: Spruce-Feathermoss transect. There is virtually no tree cover, and herbs and shrubs are growing densely through the many layers of discarded logs.

MP 26, 27 Riparian Hardwood

This is the northernmost and most recently established transect, located along the meandering Rapid River. The riparian habitat lies in a 1/4 mile strip along the river, lying lower than the adjacent bog. Vegetation data has not yet been collected in this area.

Wherever possible each habitat-type had 1.5 miles of transect running through the most homogeneous part of it that could be found. In order to keep relatively homogeneous vegetation at a distance of at least 400 ft. to each side of the line, the transects were usually laid out in smaller segments, each a minimum of 2500 feet long. These transects, 27 in all within 13 vegetation types, were the basis for observing and recording bird censuses and vegetation measurements. Each transect was carefully measured in intervals of 500 feet, with flagging and blazes (where possible) marking the trail every fifty feet. Bird tallying was then specifically indicated within the intervals along the transect.

Bird populations in the 13 plant communities were determined using the line transect technique of Emlen (1971). This consisted of recording the number and species of birds found along a 1.5 mile line transect through a homogeneous section of habitat, in the same way our transects were set up. Each bird observed was categorized by lateral distance from the transect and by its sex and age (where possible). This allows one to calculate the density for each bird species sighted on the transect using simple formulas from Emlen. Special emphasis was placed on singing male birds, as they indicate the presence of breeding pairs. Population estimates based on singing males then give measurements of breeding bird densities. Transects were walked in the early morning, usually starting at one half hour before sunrise, and continued for two to three hours. The starting point for each census was alternated between the two ends of the transect, i.e., if the transect was read starting from the north end on one course, the next census started at the south end and continued to the north. This was an attempt to balance the effects of time on the detectibility of the birds. The transects were not censused during adverse weather conditions (i.e. high winds, rain, heavy fog, etc.) when the detectibility of any bird species was likely to be less than optimum. Transects were censused at least weekly from mid-May to early August.

Using Emlen's technique, bird population desnities have been calculated for the Muskeg and Swamp Conifer-Spruce transects, and are presented in Table 1. Similar computations will be done for the remaining transects for the 1978 season by computer. At the end of the 1979 field season, the densities will again be computed and then compared with the preceeding year.

Table 1

Bird Population Densities (Singing Males per 100 acres*)

	Muskeg	Swamp Conifer-Spruce
Palm Warbler	3.90±1.60	3.33±2.51
Savanna Sparrow	11.11±6.19	
Lincoln's Sparrow	4.14±3.14	
Nashville Warbler		4.96±3.35
Yellow-bellied Flycatcher		4.34±2.45
Myrtle Warbler		1.80±2.43
Dark-eyed Junco		6.27±3.21
Chipping Sparrow	.05	4.91±2.16
Connecticut Warbler		1.44±1.44
Hermit Thrush		2.06±1.23
Gray Jay		3.17
Spruce Grouse		2.11
Raven		.82
Cedar Waxwing		.58
Blackburnian Warbler		.38
Olive-sided Flycatcher		.28
Robin		.19
Blue Jay		.19
Cowbird	.19	.14
Solitary Vireo		.05
Brewer's Blackbird	.19	
Tree Swallow	.86	

*Total breeding population is assumed to be double these figures.

Sharp-tailed Grouse Survey

Road survey routes were established in early April in an attempt to locate Sharp-tailed Grouse dancing grounds. The majority of the efforts were concentrated along state highway Rt. 72 from 3 miles north of Waskish to the northern limit of Beltrami County. During the period of 5-10 April, observers were stationed at one-mile intervals along the route. Each observer then covered a distance of one mile along the route and attempted to record the number of dancing grounds from which the calling males were heard. This proved unsatisfactory and later census efforts during 26-30 April were made by covering a given distance by vehicle with periodic stops where compass bearings were taken to pinpoint dancing grounds by triangulation. By this method 6 dancing grounds were found in the area from the Beltrami-Lake of the Woods County line and south 8 km (5 mi.) extending 1.6 km (1 mi.) to the east and west of the highway (25.6 $km.^2$ or 10 $mi.^2$). The number of males on each dancing ground was not determined due to inaccessibility and other concurrent activities. Except for bands of aspens along the road ditches, all areas surveyed were peatland communities.

Avian distribution and relative abundance during the breeding season.

Relative avian abundance and distribution among the sampled plant communities will eventually be presented in terms of numbers of birds per 40 ha. for each plant community. These data are not fully analyzed at the present time. By utilizing the absolute number of each bird species detected per census, however, one can present avian distribution and relative abundance to allow initial insight into patterns that may exist. The absolute number of each bird species detected per census is not a reliable population index since no correction is made for the lateral distribution of detected birds from the transect. It is, however, a figure that is available and useful at this time.

Avian distribution and relative abundance is presented (table 2) for the thirteen plant communities sampled during the period from 1 June to 6 July, 1978. Relative abundance is coded based on the average number of detections per census on a 1 1/2 mile transect, and on the number of censuses on which a species was detected. Those species for which strong evidence of breeding was found within each plant community are also noted. The presence of recently fledged young, observations of adults carrying food, or the location of active nests constituted evidence of breeding. This listing cannot be assumed complete since breeding status for all bird species detected within these communities has not been proven. More effort will be spent in 1979 to make the list more complete.

It should be noted that for several transects more than 50 per cent of the species detected were listed as casual in their occurrence. A bird of a given species only had to be detected once on any census to be assigned this status. When population density estimates are computed, some of these species may have such low density estimates that they will be excluded from further analyses.

To date, bird species diversity values have been determined for two of the 13 transects censused, according to the techn\que described by MacArthur (1971). The BSD value is an index derived from the summation of weighted values for each species present, according to the proportion of the total they make up. The formula is given as:

$$BSD = -\sum p_i \log p_i$$

Where p_i is the proportion of singing males per 100 acres of species i out of the total number of singing males/100 acres of all species. Singing males were assumed to be indicators of breeding pairs.

BSD values have been determined for the Muskeg and Swamp Conifer Spruce transects and are reported with the foliage height diversity values in Fig. 3. Manual calculation of BSD is very time consuming, so it is expected that the remaining values will be determined by computer.

Table 2. Avian distribution and relative abundance during the period of 1 June - 6 July, 1978.

Key: A = abundant; 10 or more detections/mile; detected on every census

R = regular; 1-9 detections/mile; detected on 75% or more of censuses

U = uncommon; detected on 25% or more of censuses; number varied

C = casual; detected on less than 25% of censuses

** = breeds in that plant community

See text for further explanation.

Table 2: BIRD SPECIES ABUNDANCE BY HABITAT

Habitat Types	Open Fen	Shrub Fen	Open Bog	Muskeg	Swamp Conifer-Spruce-	Swamp Conifer-Spruce-Featherm	Poor Swamp Forest	Swamp Conifer-Tamarack	Swamp Conifer Cedar-Spruce	Swamp Thicket	Clear-Cut	Riparian Hardwood	Mixed Upland
Avian Species													
Amer. Bittern	u								C**				
Mallard	u							**					
Pintail	C												
Blue-wing. Teal	C												
Wood Duck												C	
Com. Merganser												C**	
Broad-wing. Hawk							C						C
Marsh Hawk	C												
American Kestrel					C				C**				
Spruce Grouse													
Ruffed Grouse									C	C	C		C
Sharp-tailed Grouse		C	u	C			C						
Ruffed Grouse									C	C	C		C
Sharp-tailed Grouse		C	u	C			C						
Sora	u												
Yellow Rail	C												
Amer. Woodcock													
Common Snipe	R**	C								C			
Black Tern	C												
Mourning Dove				C			C		C	u			C
Bl-billed Cuckoo						C			C	u	C	C	C
Ruby-throat Hummg.													
Belted Kingfisher												C	
Common Flicker									C	C**	C		C
Pileated Woodpecker									C				C
Yel-bellied Sapsucker												u**	
Hairy Woodpecker								C	C	C		u	u
Downy Woodpecker													C
Bl-backed 3-toed Wood.								C	C**				
Eastern Kingbird	C						C			C			
Great Crest Flycat.						C		C	C	C	C	u	C
Eastern Phoebe												C	
Yel-bellied Flycat.					R	R	u	R	R				
Alder Flycat.		C				C		C	C	R	A		
Least Flycat.								u		C		A	A**

Habitat Types	Open Fen	Shrub Fen	Open Bog	Muskeg	Swamp Conifer-Spruce-	Swamp Conifer-Spruce-Featherm	Poor Swamp Forest	Swamp Conifer-Tamarack	Swamp Conifer Cedar-Spruce	Swamp Thicket	Clear-Cut	Riparian Hardwood	Mixed Upland
Avian Species													
East. Wood Pewee								C				R	R
Olive-sided Flycat.					C	C	u		C		u		C
Tree Swallow	R**	C	u	u	C	C	C			u	C		
Barn Swallow	C												
Cliff Swallow										C			
Purple Martin													
Gray Jay					C	C	C		C				
Blue Jay					C	u	C	u	C	u	C		u
Common Raven													
Common Crow													
Bl-capped Chick.								C**	C	C	C	C	u
Boreal Chick.						u			C				
Wh-breast. Nuthatch						C						C	C
Red-breast. Nuthatch						C		u	C	C		C	u
Brown Creeper						C			C			u	
House Wren										u**			
Winter Wren						C		u	u**				
Sh-billed Marsh Wren	R	R**								C	u		
Gray Catbird										u**			
American Robin									C**	u		u	C
Wood Thrush												u	
Hermit Thrush					R	R	R	u	u				R
Swainson's Thrush									u**				C
Veery						C		u		A	C	R	u
East. Bluebird								C		u**			
Gold-crowned Kinglet						R**							
Ruby-cr. Kinglet						u**			u				
Cedar Waxwing									C		u		
Yel-throat. Vireo													C
Solitary Vireo					C	C			u				
Red-eyed Vireo						u		u	u**	u		A	A
Warbling Vireo										C		C	
Bl & White Warbler						C		u	u	R	u		u
Gold-winged Warbler										u	u		
Tennessee Warbler													

Table 2 (cont.): BIRD SPECIES ABUNDANCE BY HABITAT

Habitat Types / Avian Species	Open Fen	Shrub Fen	Open Bog	Muskeg	Swamp Conifer-Spruce-	Swamp Conifer-Spruce-Featherm	Poor Swamp Forest	Swamp Conifer-Tamarack	Swamp Conifer Cedar-Spruce	Swamp Thicket	Clear-Cut	Riparian Hardwood	Mixed Upland
Nashville Warbler					R	A	R	A**	A*	A**	A		R
Northern Parula						C		C	U				
Yellow Warbler										R			
Magnolia Warbler									**				
Yel-rumped Warb.					U**	R**	U	U**	U				U
Bl-throat. Gr. Warb						C		C	C			R	R
Blackburnian Warb						R		U	C				U
Chestnut-sid. Warb									C	R**		R	C
Pine Warbler													C
Palm Warbler				R**	R**		R**			C			
Ovenbird								C	C	C		R	A**
No. Waterthrush												C	
Connecticut Warb					U	R	R**	A**	U		C		
Mourning Warbler												R	U
Com. Yellowthroat	R	A**				C		R	U**	A**	A**	U	
Wilson's Warbler										C			
Canada Warbler													
American Redstart									C	C		C	
Bobolink	A**	A**	R**							C			
East. Meadowlark													
Yel-Head. Blackbird	C												
Red-wing. Blackbird	R									U			
Northern Oriole										C			
Brewer's Blackbird	C		A**	C									
Common Grackle										C			
Brown-head Cowbird	C				C**		U			R**	C	C	C
Scarlet Tanager												U	U
Rose-breast. Grosbeak										R**		C	C
Indigo Bunting												C	
Purple Finch							C		C				C
Pine Siskin													
Amer. Goldfinch										C	C		
Red Crossbill													C
Savannah Sparrow	A**	C	A**	A**			R**						
LeConte's Sparrow	R*	A**											

Table 2 (cont.): BIRD SPECIES ABUNDANCE BY HABITAT

Habitat Types	Open Fen	Shrub Fen	Open Bog	Muskeg	Swamp Conifer-Spruce-	Swamp Conifer-Spruce-Featherm.	Poor Swamp Forest	Swamp Conifer-Tamarack	Swamp Conifer Cedar-Spruce	Swamp Thicket	Clear-Cut	Riparion Hardwood	Mixed Upland
Avian Species													
Sharp-tailed Sparrow	C												
Dark-eyed Junco					R**	u**	u	C					
Chipping Sparrow					R**	R**	R*						u
Clay-col. Sparrow	C	A**											
Wh-throat. Sparrow						u		R**	R**	R	R	u	
Lincoln's Sparrow				R**			u				C		
Swamp Sparrow	R**	R**								A**	u**		
Song Sparrow								C		u	R**		

Summary	Open Fen	Shrub Fen	Open Bog	Muskeg	Swamp Conifer-Spruce-	Swamp Conifer-Spruce-Featherm.	Poor Swamp Forest	Swamp Conifer-Tamarack	Swamp Conifer Cedar-Spruce	Swamp Thicket	Clear-Cut	Riparion Hardwood	Mixed Upland
# of Species Detected	24	11	5	7	15	30	20	27	41	44	24	31	37
# of Casual Species	12	5	0	3	7	16	8	12	26	21	12	14	19

The value of further censusing along these same transects throughout the 1979 breeding season cannot be stressed enough. The increased sample size would help decrease the variability in this year's population values for singing males/100 acres (see pop. densities, table 1), as well as give further data to elucidate apparent patterns in population peaks and lows. In several cases a single bird species was found to suddenly appear or disappear from a habitat type. Further censusing would give more conclusive evidence as to whether this phenomenon was an exception or an annual pattern.

Finally, after finding relatively high species densities from netting in a Spruce Island habitat it has become apparent that census data is needed from this vegetation type--thus far not included in the already established transects. Therefore a transect needs to be established and censused throughout the 1979 season in the same Spruce Island where the net plot is already located. Data from this transect would not only be valuable (and necessary) in relating population densities with the other transects, but also as a tool in relating densities determined by censusing to densities found from netting. Census densities and netting densities are now valuable in their own context but we must have census data from the Spruce Island before the two can be related. If the two can be related, then it may be possible to extrapolate birds/100 acres or 40 ha. from netting data collected after nesting is completed. During this period it is no longer dependable to census birds since the males are not singing, individuals become more elusive, and migrating groups may be moving through the study area.

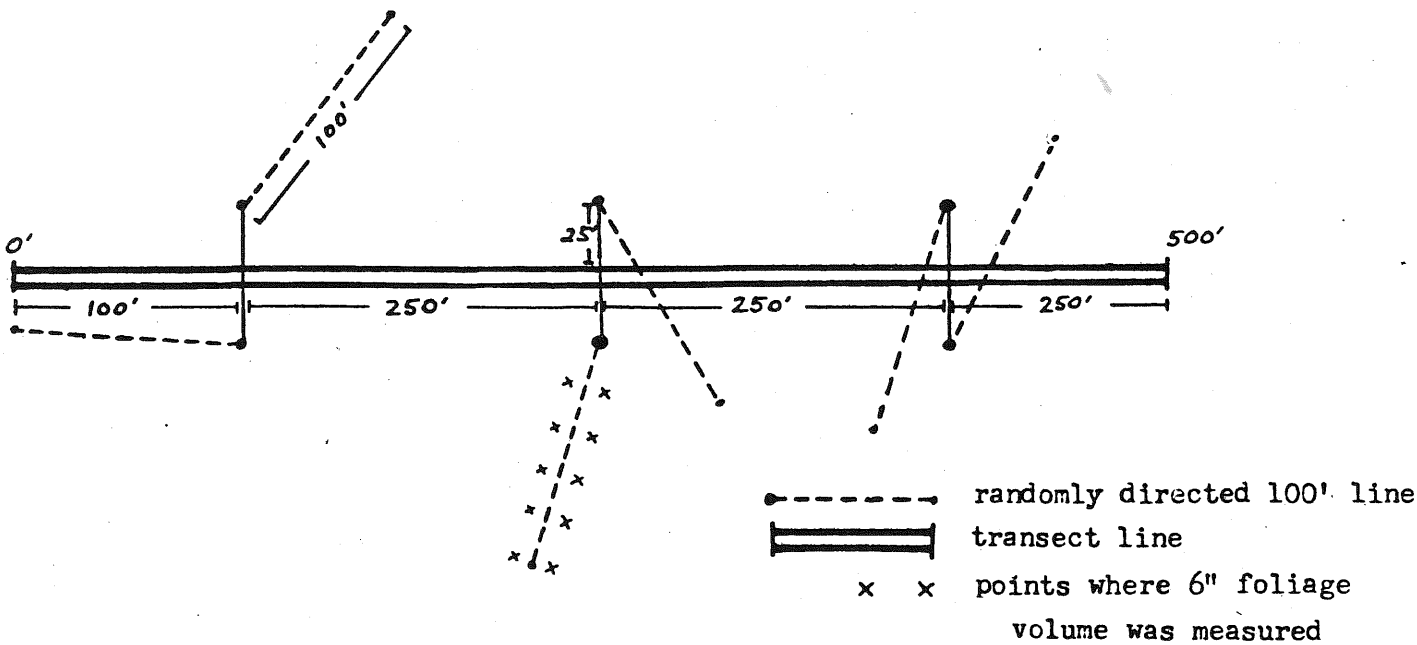


Fig. 1. **Sampling Method for Foliage Volume Along a 500 ft. Interval**

Foliage Density and Foliage Height Diversity

Foliage density measurements have been taken along all transects with the exception of the Rapid River. The sampling method is diagrammed in Fig. 1. Stopping points were determined at the center of, and 100 ft. from each endpoint of each 500 ft. interval along all transects. From every stopping point, two origin points were marked 25 ft. on either side of the transect. A one hundred foot line was then marked off in a straight random direction from this point, determined by spinning a stick and taking a compass bearing on the stick. All foliage density measurements were then taken along this line marked by a calibrated 100' tape.

Foliage density measurements were made using the board technique as described by MacArthur and MacArthur (1961). This involved moving a 10"x18" board away from the origin of the sampling line at a constant horizontal level until an observer standing at the origin point considered the board to be 50 per cent obscured by foliage silhouette. This distance was recorded and will be referred to as d. Distances along each 100' line were recorded in this way at each of the following levels from the ground: 6', 2', 5', 10', 15', 20', 25', and every ten feet thereafter.

According to the Poisson distribution, the probability that one half of the board will remain unobscured at distance d is equal to e^{-kd}. That is;

$$e^{-kd} = 1/2$$

Here k is the value we are seeking, namely square feet of foliage silhouette per cubic foot of space. Solving for k, this same equation becomes:

$$k = \frac{\log_e 2}{d} = \frac{.69}{d}$$

By substituting our distances into this formula and averaging the results for each horizontal layer, k values were determined for five of our transects. These are presented in Fig. 2 plotted at each height so that a visual "foliage density profile" (MacArthur and MacArthur, 1961) results. This results in a simple summation of foliage structure useful for comparison of different vegetation types. In Fig. 3 the previously presented profiles have been lumped into two general profiles of Muskeg and Swamp Conifer-Spruce.

Using the same formula as used for bird species diversity, a value MacArthur (1961) called "foliage height diversity", FHD, was determined. The FHD value describes the relative distribution of foliage density throughout the aforementioned horizontal strata. Actually the original horizontal divisions were lumped into three arbitrarily chosen levels; stratum 1 being the sum of the average k values for 6" and 2', stratum 2 the sum of k values for 5-15', and stratum 3 the sum of the k values for the remaining height categoreies. Again, the formula used was:

$$-\Sigma\, p_i \log_e p_i = \text{FHD}$$

where p_i is the proportion of the total foliage that lies within the i^{th} stratum, here either the first, second, or third.

These values are best interpreted by comparison between FHD's of differing vegetation types. For example the FHD value for MP5 and 6, the Muskeg transects, is given as 0.222. This is small when compared to the value for the Swamp Conifer-Spruce transects, which is 0.980. Intuitively this makes sense, since the profile for the latter shows much more foliage density through many more of the measured strata than the Muskeg profile.

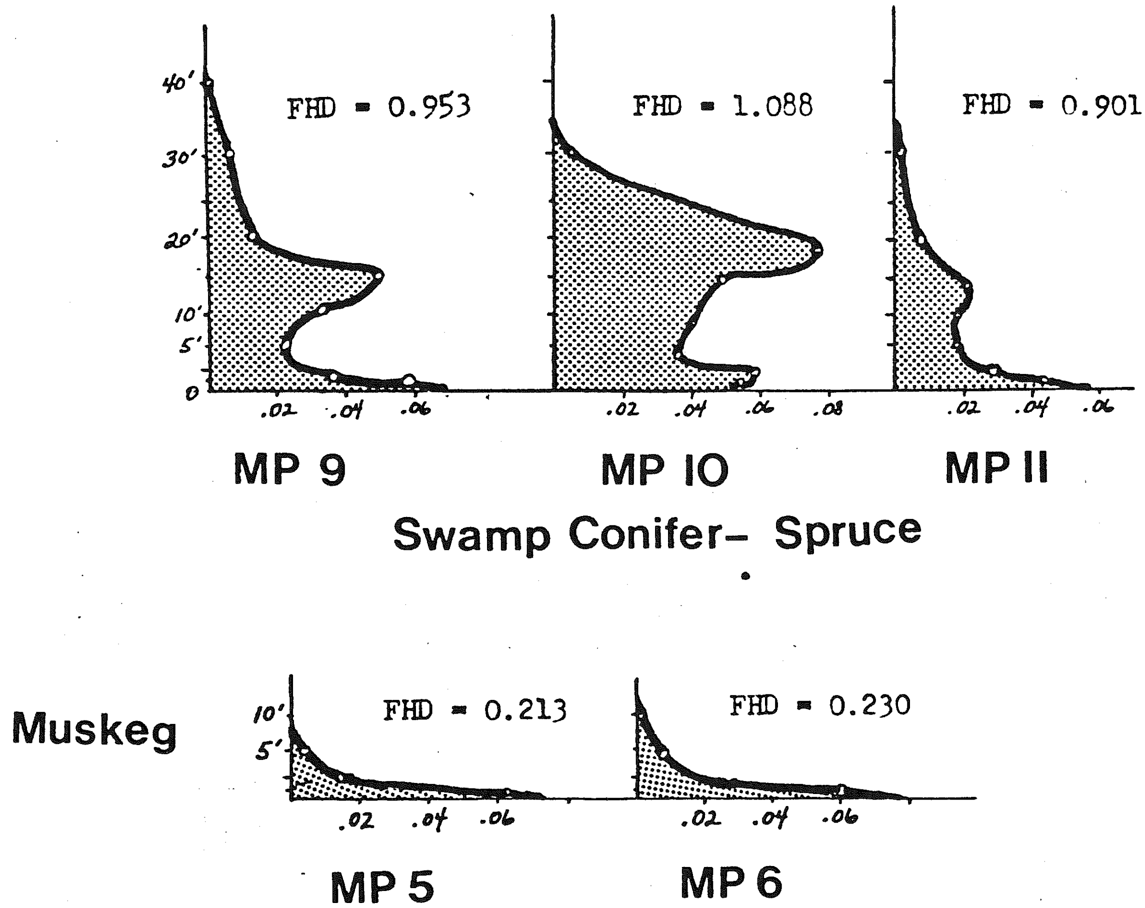


Fig. 2 : Foliage density profiles for each Muskeg and Swamp-Conifer transect separately. The x-coordinate measures foliage density in terms of foliage silhouette in square feet per cubic foot of volume. The y-axis represents feet above the ground. FHD is foliage height diversity.

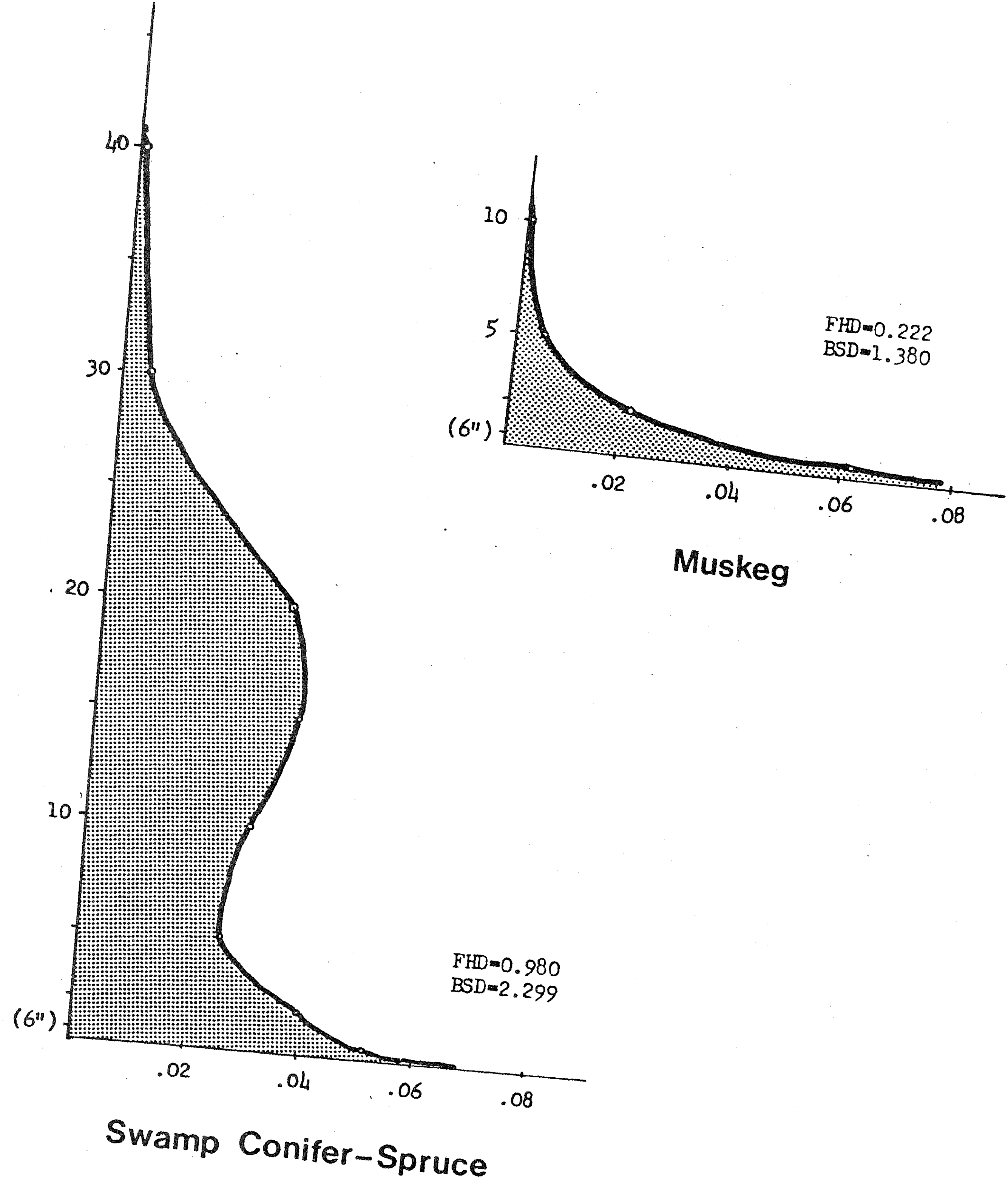


Fig.3 : Foliage density profiles for all Muskeg transects and all Swamp Conifer Spruce transects averaged together. The x-coordinate measures foliage density in terms of foliage silhouette in square feet per cubic foot of volume. The y-axis represents feet above the ground. FHD is foliage height diversity, and BSD is bird species diversity.

Foliage height diversity values not only serve to allow us to compare our own study transects, but also facilitate comparisons with other studies (e.g., MacArthur and MacArthur, 1961; Willson, 1974) which have used this same technique. Once all of our values are determined and foliage density profiles are completed, we will have a powerful tool not only for describing the structure of the vegetation, but also for relating bird species found within the vegetation types, and bird species diversity with foliage height diversity.

It should be noted that due to the presence of hummocks in many of our study areas, a slight modification in MacArthur's technique was necessary in measuring the 6" vegetation layer. At five points along the 100' sampling line the board placed on the ground at a double arm's length from the line and the percent of the board that was obscured was estimated. At each of these five points one determination was made on each side of the line making a total of 10 readings per line (see "Methods" fig. 1.). The same formula was used (e^{-kd} = fraction of board unobscured) to find k, assuming that the distance (d) from the observer's eye to the board was always 2 feet.

Plant Relevés

The relevé method was used to describe the transect habitats in a semi-quantitative manner. This method is based on dividing the habitat into height strata and estimating the total cover of various life-form types in each height stratum. The symbols used for this section are those of Küchler (1967). Within each of these categories, inidivdual species are listed and the cover and sociability of each species is estimated. The symbols used for this portion are from the Braun-Blanquet Floristic System (1932). Finally, flowering and fruiting are indicated by appropriate symbols. The completed relevés allow one to visualize the structure and species composition of the community described.

Most habitat types sampled are represented by two or more transects totalling 7500 feet in length. One of the prerequisites for use of the relevé method is that the area described must be homogeneous. Although each habitat type was a definable entity, some were considered heterogeneous by the standards of the releve method. Therefore, for the purpose of the relevé descriptions, some of the habitats were divided into homogeneous subunits. The number of feet of transect represented by the relevés and the total number of feet of transect in that habitat type are indicated on each relevé.

Standard procedure was to locate a 20 x 20 m. relevé plot in an area representative of a homogeneous portion of the habitat type to be described. Some habitats posed special problems. Some transects contained small areas where the trees were of much higher and/or lower density than the majority of the transect. In this case an area of intermediate density considered to be representative of the average density for the whole transect was selected for the location of the relevé plot. In two areas (Swamp Thicket and Cutover) a 20 x 20 m. plot was not feasible because of tall and very dense vegetation. The plot size in these areas was 5 x 80 m. Open Fen contained many herbs at low densities. The "relevé" for this area is not comparable to the others. It actually is equivalent to a species list with estimates of relative abundance.

Identification was done to species whenever possible. At times the absence of key structures (flowers, fruits) allowed identification to genus only. It was not possible for us to identify most graminoids and bryophytes. Estimates of total cover are presented in these strata. Grass species in flower were identified and listed but many were not in flower. Lists in these areas are far from exhaustive.

The actual relevé sheets for the transects will not be presented here, but have been completed and will be used in our final report. The number of relevés necessary for each transect and the general format we have recorded them in is presented in the following pages.

List of Relevés by Habitat type (# after each releve is number of feet of transect represented by that releve).

1.	Shrub Fen	tot. feet =	7500	T. #1 & 2
	relevé	1-1	7500	
2.	Open Fen	tot. feet =	7500	T. #3 & 4
	relevé	3-1	7500	
3.	Muskeg	tot. ft.	7500	T. #5 & 6
	relevé	5-1	5100	
	relevé	5-2	800	
	relevé	5-3	1600	
4.	Open Bog	tot. ft.	7500	T. #7 & 8
	relevé	7-1	7500	
5.	Swamp Conifer Spruce	tot. ft.	7500	T #9,10, & 11
	relevé	9-1	7500	
6.	Poor Swamp Forest	tot. ft.	7500	T #12 & 13
	relevé	12-1	4100	
	relevé	13-1	800	
	relevé	13-2	2100	
7.	Swamp Thicket	tot. ft.	9000	T #14 & 15
	relevé	14-1	3000	
	relevé	14-2	1000	
	relevé	14-3	2000	
	relevé	15-1	3000	
8.	Swamp Conifer Tamarack	tot. ft.	7500	T. #16 & 24
	relevé	16-1	3000	
	relevé	24-1	2900	
	relevé	24-2	1600	
9.	Swamp Conifer Spruce Featherm.	tot. ft.	8000	T. # 17 & 18
	relevé	17-1	1400	
	relevé	17-2	350	
	relevé	17-3	2600	
	relevé	18-1	2750	
	relevé	18-2	250	
	relevé	18-3	650	
10.	Swamp Conifer: Cedar-Spruce	tot. ft.	7500	T. #19, 20 & 21
	relevé	19-1	1000	
	relevé	19-2	1500	
	relevé	20-1	2500	
	relevé	21-1	1700	
	relevé	21-2	800	

11.	Upland	tot. ft. =	7500	T. #22 & 23
	relevé	22-1	2000	
	relevé	22-2	1500	
	relevé	23-1	2500	
	relevé	23-2	1500	
12.	Clearcut Swamp Conifer Spruce	tot. ft. =	2000	T. #25
	relevé	25-1	2000	

Format for Relevé sheets

General name of habitat type
Code number for relevé (first # is transect #)
Date

Location on transect of relevé plot (20 x 20 m)
Portion of transect represented by relevé, # feet of total feet of that habitat type

Symbols

Life-form categories (after Küchler)

E Needleleaf evergreen
N Needleleaf deciduous
D Broadleaf deciduous
B Broadleaf evergreen
H Forbs
G Graminoids
L Lichens, mosses

Height (stratification)

8 > 35m
7 20-35 m
6 10-20 m
5 5-10 m
4 2-5 m
3 0.5-2 m
2 0.1-0.5 m
1 < 0.1 m

Coverage

c Continuous > 75%
i Interrupted 50-75%
p parklike 25-50%
r rare 5-25%
b barely present 1-5%
a almost absent, v. scarce <1%

Cover-degree/abundance (after Braun-Blanquet)

r single occurrence
+ occasional, cover <5%
1 plentiful, cover <5%
2 very numberous, cover 5-25%
3 any number of indiv., cover 25-50%
4 any number of indiv., cover 50-75%
5 any number of indiv., cover 75-100%

Sociability

1 Growing singly
2 Grouped, few individuals
3 Large group, many indiv.
4 Small colonies, extensive patches, broken mat
5 Extensive mat

Condition & vitality

bl blooming
fr fruiting

Each life-form group in each of Küchler's height categories is given a cover estimate i.e. E6i. Individual sp. are listed under those categories and assigned cover and sociability symbols i.e. Picea mariana 3.1 (after Braun-Blanquet).

Tree Counts

In addition to foliage density profiles and relevés the vegetation along our transects is being described and quantified from tenth acre plot samples using techniques similar to those outlined by James and Shugart (1970). These techniques were offered as a means to standardize vegetation descriptions for bird censuses such that both the avifauna and habitat of different areas can be readily compared. In carrying out "tree counts" we not only counted all tree species of designated size classes (diameter at breast height) within each tenth acre plot, but also shrub stems and saplings were counted, and canopy cover estimated.

The method used in sampling for tree counts is diagrammed in figure 4. At the midpoint of each 500 foot interval of each transect, a distance of 50 feet perpendicular to the transect line on each side was measured. With these two points as centers, two tenth acre circles (37 foot radius) were flagged and within these all trees were tallied according to their diameter size class (see table 3). For shrub stem counts and canopy cover estimation, two randomly directed radii were marked using ropes 37 feet long. Canopy cover was evaluated by ten overhead sightings along each radius with a vertically held tube. The cardboard tube was equipped with cross nairs and "plumb-bob " and mounted on a stick, so that when held vertically a foliage "hit or miss" could be easily distinguished at a level above ten feet. Percent canopy cover was then determined from the fraction of total sightings that "hit" foliage (James and Shugart, 1970).

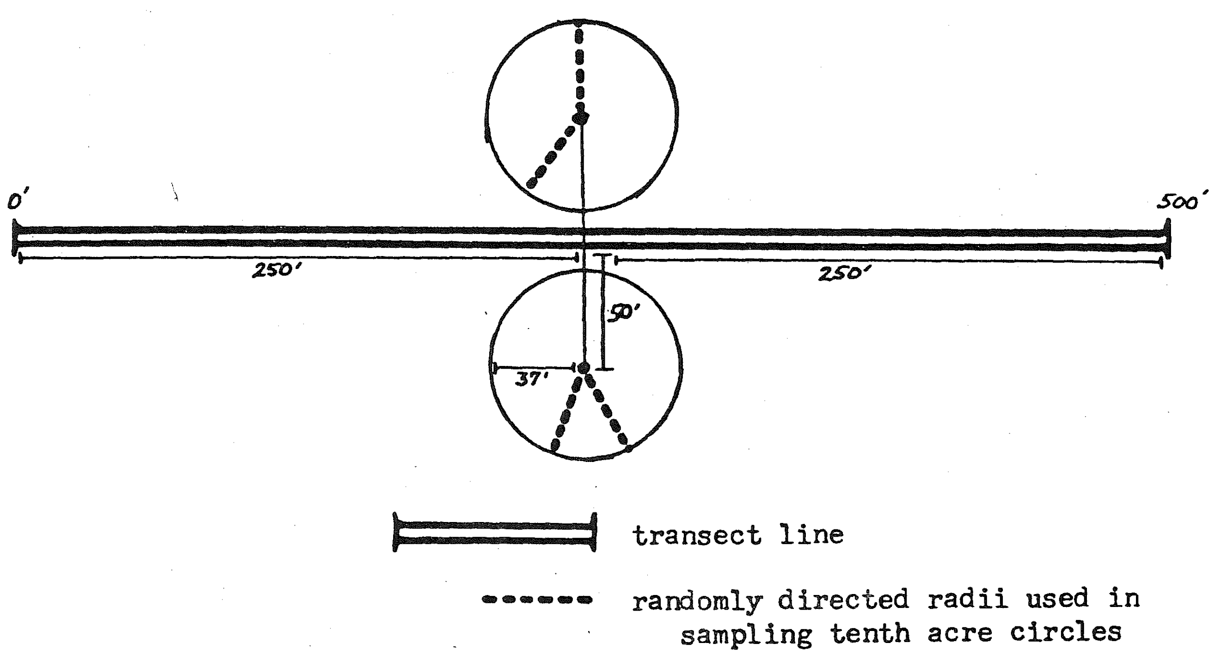


Fig. 4. **Sampling Method Used for Tree Counts**

Tree counts were carried out during the 1978 field season during the hours of the day when birds were least active, usually after morning censusing and netting were finished, or when inclement weather rendered censusing impossible. All but nine of the twenty six transects have been completed, and average values have been computed for each. These values are presented in table 4. In the final analysis correlations will be sought regarding the occurrence of specific trees and shrubs and bird species. These tree counts also give us a tool for comparing species makeup between our transects, as well as species composition in other studies which have used this technique.

Table 4

Species:Size Class		Shrub	Fen	Open Fen String Fen		Muskeg		Open Bog		Swamp Conifer Spruce		Poor Swamp Forest		Swamp Conifer: Spruce Feather Moss		Swamp Conifer: Cedar-Spruce		Swamp Conifer Tamarack
		MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8	MP9	MP10	MP12	MP13	MP17	MP18	MP19	MP21	MP24
Picea mariana	A	*	*	*	*	129 (105)	114 (38.9)	4.6 (6.6)	0.9 (1.9)	59.9 (24.3)	59.7 (15.5)	33.2 (12.1)	26.6 (25.0)	19.1 (28.5)	8.8 (4.4)	*	*	7.4 (5.4)
	B	*	*	*	*	63.4 (53.5)	70.1 (29.6)	1.1 (1.8)	0.2 (0.6)	54.6 (23.1)	83.1 (12.4)	18.2 (20.0)	27.7 (28.0)	52.4 (54.4)	64.3 (39.6)	*	*	4.2 (5.8)
	C	*	*	*	*	*	*	*	*	38.4 (12.2)	53.6 (10.7)	6.9 (10.8)	7.3 (8.5)	57.9 (32.2)	68 (28.2)	0.1 (0.3)	*	0.4 (1.2)
	D	*	*	*	*	*	*	*	*	1.5 (1.1)	0.6 (0.7)	*	1.2 (2.0)	16.7 (10.0)	14.6 (9.6)	*	*	*
	E	*	*	*	*	*	*	*	*	*	*	*	*	0.09 (0.30)	*	0.5 (1.5)	*	*
Larix laricina	A	*	*	*	*	0.1 (0.3)	0.2 (0.4)	0.8 (1.8)	1.2 (2.2)	*	*	33.6 (24.6)	3.0 (2.6)	0.14 (0.46)	*	*	*	14.8 (15.3)
	B	0.06 (0.2)	*	*	0.07 (0.3)	0.06 (0.2)	0.2 (0.4)	0.3 (0.8)	0.3 (0.5)	7.6 (4.9)	1.9 (1.4)	14.3 (13.0)	32 (19.1)	1.45 (2.13)	0.1 (0.3)	*	*	20.1 (13.1)
	C	*	*	*	*	*	*	*	*	2.5 (2.6)	0.1 (0.3)	10.6 (7.4)	18.5 (13.0)	3.23 (5.12)	*	0.9 (2.4)	*	75.1 (11.2)
	D	*	*	*	*	*	*	*	*	*	*	0.17 (0.6)	*	0.45 (1.34)	*	*	*	2.6 (3.5)
White Cedar Thuja occidentalis	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	24.0 (33.1)	16.9 (22.7)	1.8 (4.3)
	B	*	*	*	*	*	*	*	*	*	*	*	*	*	*	81.9 (48.7)	32.3 (21.5)	1.1 (1.7)
	C	*	*	*	*	*	*	*	*	*	*	*	*	*	*	58.3 (32.8)	48.0 (16.8)	*
	D	*	*	*	*	*	*	*	*	*	*	*	*	*	*	17.2 (5.0)	18.7 (12.7)	0.1 (0.3)
	E	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.5 (1.2)	1.8 (1.7)	*
	F	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1 (0.3)	0.1 (0.3)	*
Abies balsamea	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	37.9 (26.7)	43.8 25.7)	0.2 (0.5)
	B	*	*	*	*	*	*	*	*	*	*	*	*	*	*	63.7 (43.4)	93.5 (43.8)	*
	C	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14.4 (11.6)	12.6 (6.4)	*
	D	*	*	*	*	*	*	*	*	*	*	*	*	*	*	2.6 (2.2)	0.7 (1.2)	*
	E	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.3 (0.5)	*	*
	F	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1 (0.3)	*	*
Betula papyrifera	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1 (0.3)	*
	B	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.5 (1.5)	*
	C	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.3 (0.6)	*
	D	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.5 (1.0)	0.4 (0.7)	*
Populus	D	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.3 (0.9)	*
	E	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1 (0.3)	*
Acer rubrum	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.06 (0.2)
Pinus strobus	D	*	*	*	*	*	*	*	*	*	*	*	*	0.05 (0.2)	*	*	*	*
Fraxinus	A	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.1 (0.3)	*
Dead Trees (all species)	A	*	*	0.3 (0.7)	0.8 (1.2)	4.8 (4.2)	2.6 (2.1)	9.5 (5.1)	13.2 (4.9)	*	*	*	0.8 (1.5)	1.95 (2.06)	*	5.0 (5.9)	1.6 (1.6)	1.1 (1.4)
	B	*	*	0.3 (0.6)	0.7 (1.0)	10.2 (4.5)	6.0 (2.7)	15.8 (12.8)	13.2 (7.4)	30.0 (7.2)	23.3 (6.1)	8.1 (7.5)	27.1 (15.2)	10.7 (6.3)	*	17.6 (23.9)	11.6 (9.1)	20 (7.9)
	C	*	*	0.06 (0.24)	0.5 (1.1)	*	*	*	*	4.7 (7.4)	5.3 (1.7)	2.5 (2.3)	2.4 (2.2)	3.9 (4.4)	*	2.7 (2.4)	2.3 (2.2)	3.2 (2.1)
	D	*	*	*	*	*	*	*	*	*	*	0.05 (0.2)	0.13 (0.34)	0.23 (0.52)	*	0.7 (0.6)	1.1 (1.0)	*
	E	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.8 (0.9)	0.3 (0.5)	*
Stem Counts Betula pumila		1766 (909)	1467 (151.7)	19.1 (46.2)	61.6 (19.2)	*	*	*	*	*	*	7.6 (17.0)	38.9 (63.9)	23.5 (70.4)	*	*	*	325.1 (150)
Salix		1.2 (4.6)	*	*	*	*	*	*	*	*	*	*	*	11.2 (39.8)	*	3.6 (7.7)	34.1 (61.9)	230.0 (107)
Cornus stolonifera		*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.2 (3.6)	28.2 (38.4)	55.4 (57.4)
Prunus sp.		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.7 (2.8)
Lonicera		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.2 (3.6)	43.9 (108)
Rhamnus		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.5 (10.5)	10.5 (26.0)
Ribes		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.5 (10.5)	3.3 (13.5)
Amelanchier		*	*	*	*	*	*	*	*	*	*	*	*	*	5.9 (17.7)	*	*	*
Alnus rugosa		*	*	*	*	*	*	*	*	*	*	*	*	30.0 (72.3)	*	*	*	*
Unknown		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5.9 (17.7)	*
% Canopy Cover		0	0	0	0	0	0.7	0	0	10	12	6.0	9.4	47	73	64	67	41

* Values for 1/10 acre circles.

Table 4. Transect Description by Tree Counts, Stems Counts and Canopy Cover. All trees are divided into size classes as follows: DBH < 3 in. and tree < 4 ft. in height, A; DBH <3 in. and tree > 4 ft. in height, B; DBH 3-6 in.,C; DBH 6-9 in., D; DBH 9-12 in., E; and DBH 12-15 in., F. Shrub stems were counted where stems leave the ground. Numerical value indicate ave. trees or stems per 0.1 acre, followed by the standard deviation in parentheses. Asterisks represent the absence of a particular species or size class. Seven transects are yet to be completed. DBH is diameter at breast height.

The Arthropod Collections

The following data are presented without detailed comment. We recognize the importance of these invertebrates as food resources for vertebrates but these collections have not yet been related to the bird data. The data for Muskeg and Spruce Island show some major differences in invertebrate composition between the two study areas.

When a capitol letter precedes a number it indicates:

A = size class. The following system was used: A = 0-3mm, B =3-5 mm, C = 5-8 mm, D = 8-12 mm, E = 12-15 mm, F = 15-20 mm, G = 20-25 mm, H = 25-30 mm, I = 30-35 mm, & J = 35-40 mm.

Net A had a 14.5 inch diameter and was 24 inches deep.

Net B was 15.625 inches in diameter and was 24 inches deep.

Table 5. Insect Sweeps

	MUSKEG				SPRUCE ISLAND			
	July 22		July 22		July 24		July 24	
	300 sweeps denser spruce		700 Sweeps sparser spruce		500 Sweeps sparser spruce		700 Sweeps sparser spruce	
Acari	A	148	A	226	A	155	A	74
Araneida	A	64	A	202	A	447	A	468
	B	34	B	29	B	15	B	51
	C	11	C	12	C	3	C	2
	D	1						
		110		243		465		521
Coleoptera	A	5	A	13	A	13	A	27
	B	16	B	7	B	4	B	14
	C	2						
		23.		20		17		41
Collembola	A	18	A	63	A	37	A	39
Diptera	A	170	A	1021	A	728	A	826
	B	46	B	85	B	66	B	232
	C	42	C	55	C	61	C	74
	D	2	D	8	D	2	D	1
			E	1				
		260		1107		857		1133
Hemiptera	A	12	A	7	A	86	A	126
	B	9	B	7	B	6	B	23
	C	19	C	7	C	7	C	5
	D	3	D	1				
			E	1				
		43		23		99		154
Homoptera	A	129	A	129	A	42	A	151
	B	431	B	478	B	122	B	646
	C	3	C	12	C	5		
	D	3	D	7	D	3		
		566		626		172		797
Hymenoptera	A	44	A	85	A	56	A	249
	B	7	B	14	B	17	B	38
	C	6	C	8	C	5	C	4
			D	1				
		57		108		78		291
Lepidoptera					A	1	A	4
	B	3			B	1	B	5
	C	15			C	14	C	35
							E	2
		18				16		46

Table 5. (continued)

Insect Sweeps

	MUSKEG				SPRUCE ISLAND			
	July 22		July 22		July 24		July 24	
	300 sweeps denser spruce		700 Sweeps sparser spruce		500 Sweeps sparser spruce		700 Sweeps sparser spruce	
Neuroptera	D	1	A	1	B	4	A	2
			B	2	C	6		
			C	7		10		
				10				
Orthoptera	D	2	C	2	C	1		
	E	1	D	6				
	F	1	E	7				
	G	1		15				
		5						
Psocoptera	A	1	B	1	A	11	A	3
	B	2			B	2	B	3
		3				13		6
Thysanoptera	A	8	A	81	A	12	A	49

Bird Netting and Banding

The netting and banding of birds within our three net plots has proven to be a very important part of our study, giving information not only on species presence or absence, but also on territory size and location of breeding pairs, appearance and disappearance of individuals due to changing activity patterns, breeding and molt condition, age, and weight of individuals. All birds caught were banded (some color marked) and data recorded regarding age, weight, sex, breeding condition, molt, and additional comments.

The three rectangular net plots ranged from 35 to 56 twelve by three meter mist nets placed at grid intersections fifty meters apart. After initial opening of the nets, each was checked at time intervals of about one and a half hours and captured birds were returned to a centrally located banding station for processing. All netting was limited either to morning hours, or at times when cool weather permitted, extended through the afternooon. During the 1978 field season (May through September) a total of 2,028 birds were banded. In addition to this, 476 birds were recaptured at least once, and many individuals were recaptured several times throughout the season.

When examining netting data the numbers of birds captured can be standardized by presenting them in terms of birds caught per net hour. Net hours are determined on a daily basis; for example, if 35 nets are open a total of 4 hours the total net hours for that day would be 4x35=140. Then, if during the course of that day fifteen birds were captured (including recaptures) the standardized birds/net hour figure would be 15/140=0.107. To make these values easier to work with, we usually multiply them by 100 to give birds/net hr. x 100.

Initially net plots were set up in four of our study areas, namely, Spruce Island, Swamp Conifer: Cedar, Swamp Conifer: Tamarack, and Swamp Conifer: Spruce. Netting was discontinued in Swamp Conifer: Spruce in June because of poor netting success, which may have been due to low bird densities in this habitat or poor "netability". Of the remaining three the Spruce Island net plot appeared to be the most densely populated throughout the breeding season, but during the fall migration the numbers netted there were dwarfed by the incredible number of birds that moved through the Swamp Conifer: Tamarack net plot.

The total birds/net hour x 100 was plotted through time for each of the three net plots and is presented in figs.5, 7 and 9. The total of recaptures was also plotted to show that a good proportion of the birds captured throughout the breeding season were actually resident breeding pairs. However, the difference between total captures and recaptures should not be taken as indicating non-residents, since not all the breeding birds were banded in the beginning of the season.

Within the Spruce Island net plot (fig. 5) three major peaks can be noted in total captures between May 7 and September 6. The first occurred within the vicinity of May 21 when birds were migrating through or arriving and establishing breeding territories. Fig. 6 shows a breakdown of this peak into four of the most prevalent warbler Species, and it can be seen that Palm, Nashville, and Myrtle Warblers were present in similar proportions. Referring back to fig. 5, after the establishment of breeding territories there was a lull in activity through June while females were incubating and rearing hatchlings. The second peak then occurred when the first broods fledged from the nests and began getting caught in the nets. This peak is actually made up of two successive peaks (see fig. 6), the first occurring for Nashville Warblers on July 3 when they comprised 43 per cent of all birds caught that day. Later, on July 20 there was a large peak in the number of Palm Warblers netted (most of which were hatching-year birds). On that day 62% of all the birds netted were Palm Warblers. These staggered peaks may indicate some degree of habitat partitioning between the two species, although another season's data would be necessary to confirm this. Field observations, however, noted almost a total disappearance of one of the species while the other was most prevalent.

Seasonal peaks similar to those described for the Spruce Island plot can be found to a lesser degree in the graph of the Swamp Conifer: Tamarack plot (see fig. 7). Although there is a midseason peak in the bird numbers, it is not nearly so pronounced as in the Spruce Island. However, there are periods in both the Swamp Conifer: Tamarack and Cedar net plots where we are lacking data, so these graphs will need revision following the 1979 field season. It is interesting to note, however, that while the Tamarack net plot was significantly lower in netted birds than the Spruce Island net plot through most the season, during the fall migration (beginning about August 20) the birds/net hour was so high that it dwarfed the volume caught at the same period on the Spruce Island. Such incredible numbers of birds moved through the tamarack swamp that sometimes we could not process all the birds caught within a day's time. Clearly this indicates that the Swamp Conifer: Tamarack habitat must be an important molting and migratory stopover site.

In the Tamarack net plot, during fall migration Nashville Warblers far outnumbered other species caught (see fig. 8). However, the groups of birds observed moving through the forest were always mixed species flocks, with significant numbers of Myrtle, Tennessee, Black and White, and Connecticut Warblers, as well as many other species caught in lesser numbers.

The Swamp Conifer: Cedar net plot (fig. 9) also shows spring and fall migration peaks, as well as a midsummer peak of hatching year birds. The fall migration was not nearly so dramatic in the Cedar net plot as in Tamarack or Spruce Island, indicating either that this is not as important an area for migratory stopovers or that we simply weren't there when the birds were.

Fig. 5.

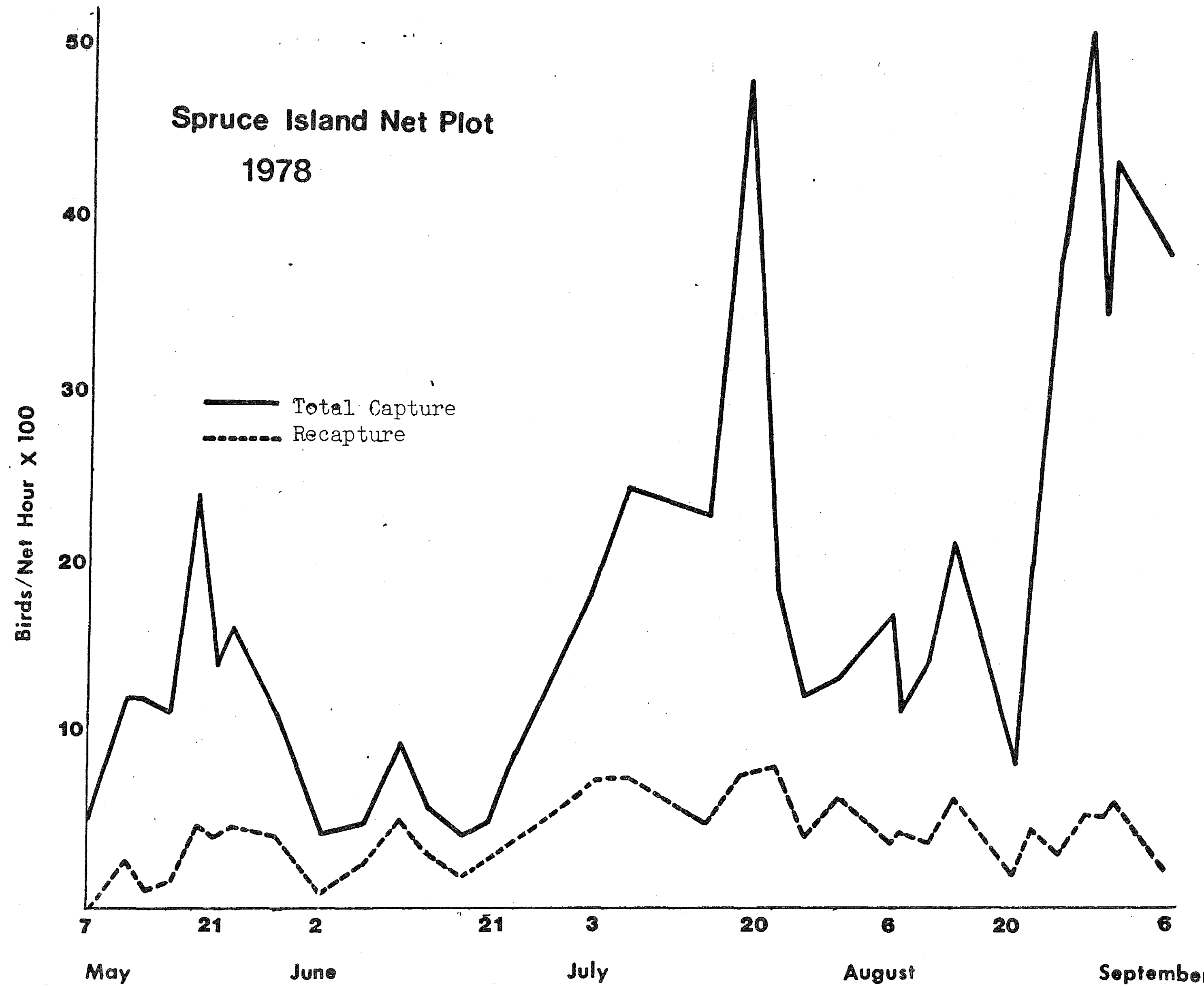


Figure 5. Standardized netting totals from the Spruce Island net plot indicate three major bird activity peaks through the netting season: 1) during spring migration and early territory establishment: 2) after first broods fledged from the nest; 3) during the fall migration. Recapture levels stayed fairly steady throughout the netting season.

Fig. 6.

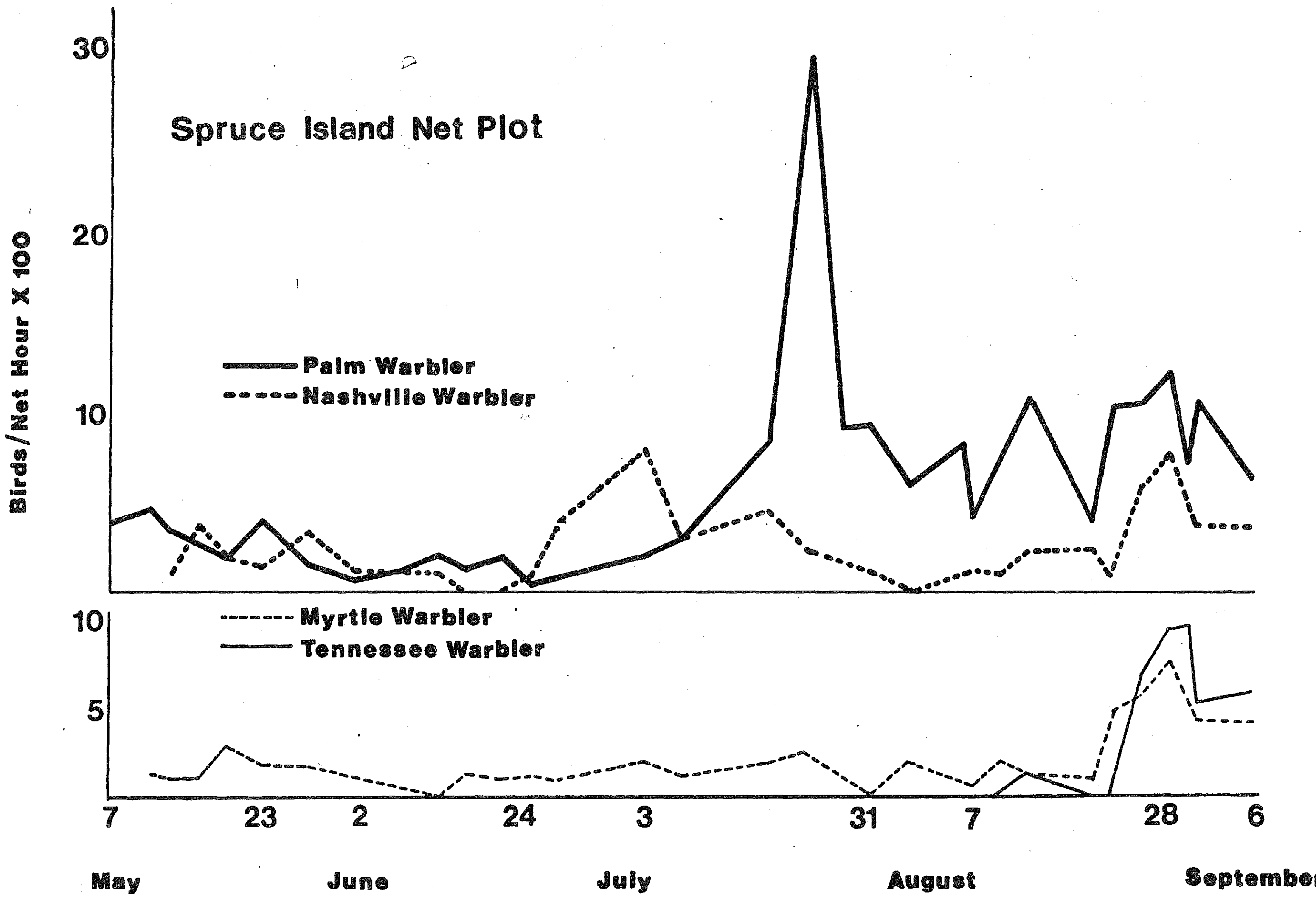


Figure 6. Four individual species netted in relatively large numbers are plotted here to show their respective peaks. Although the peak of total captures around July 20 (see fig. 5) was made up primarily of Palm Warblers, the fall peak was made up of close to equal proportions of those species shown here, in addition to lesser numbers of other species.

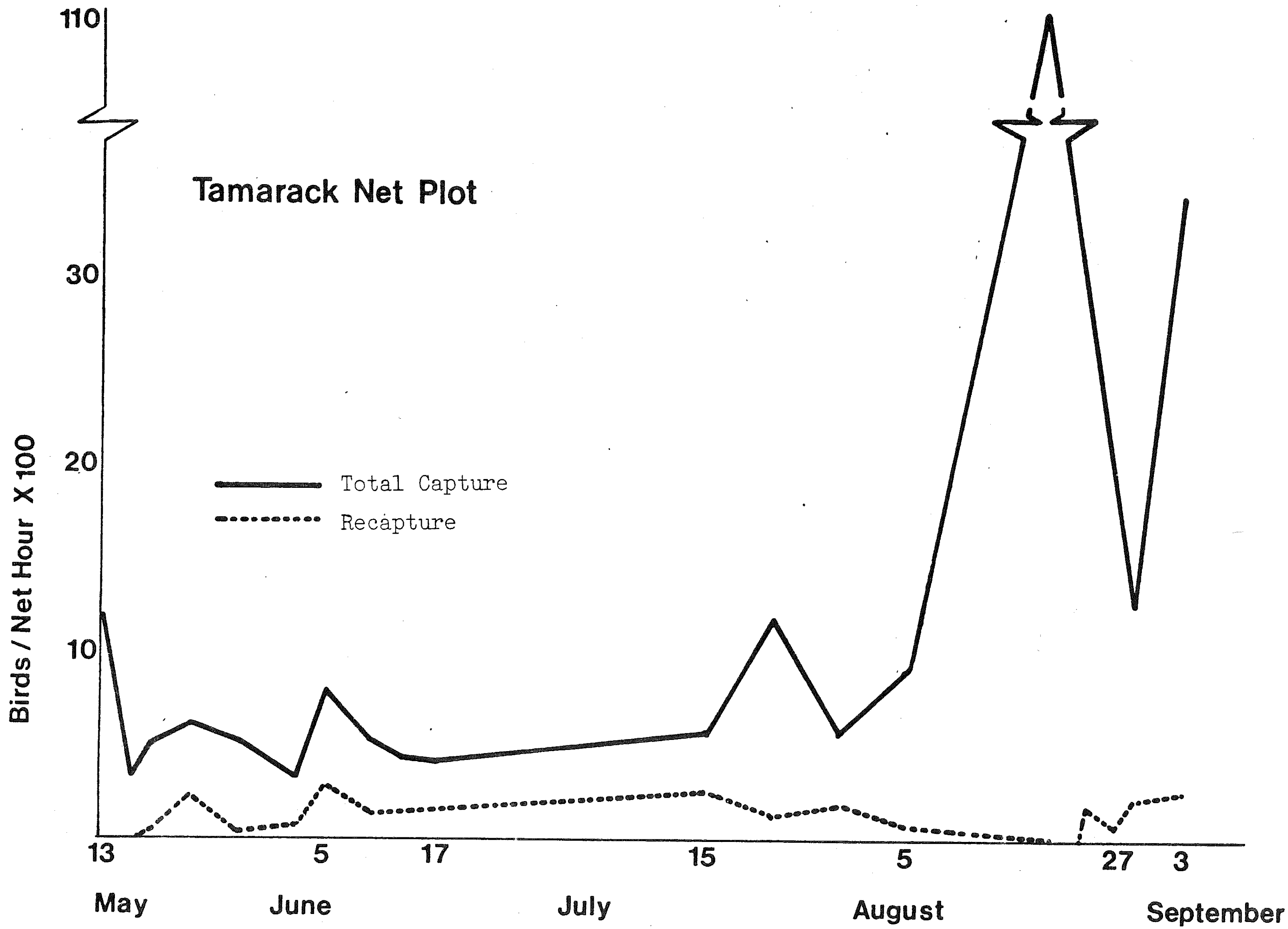


Figure 7. Although not as distinct as seen in the Spruce Island, the Swamp Conifer: Tamarack netting totals also reflect the same three peaks through the netting season. Bird numbers during the fall migration reached phenomenal levels in this area.

Fig. 7.

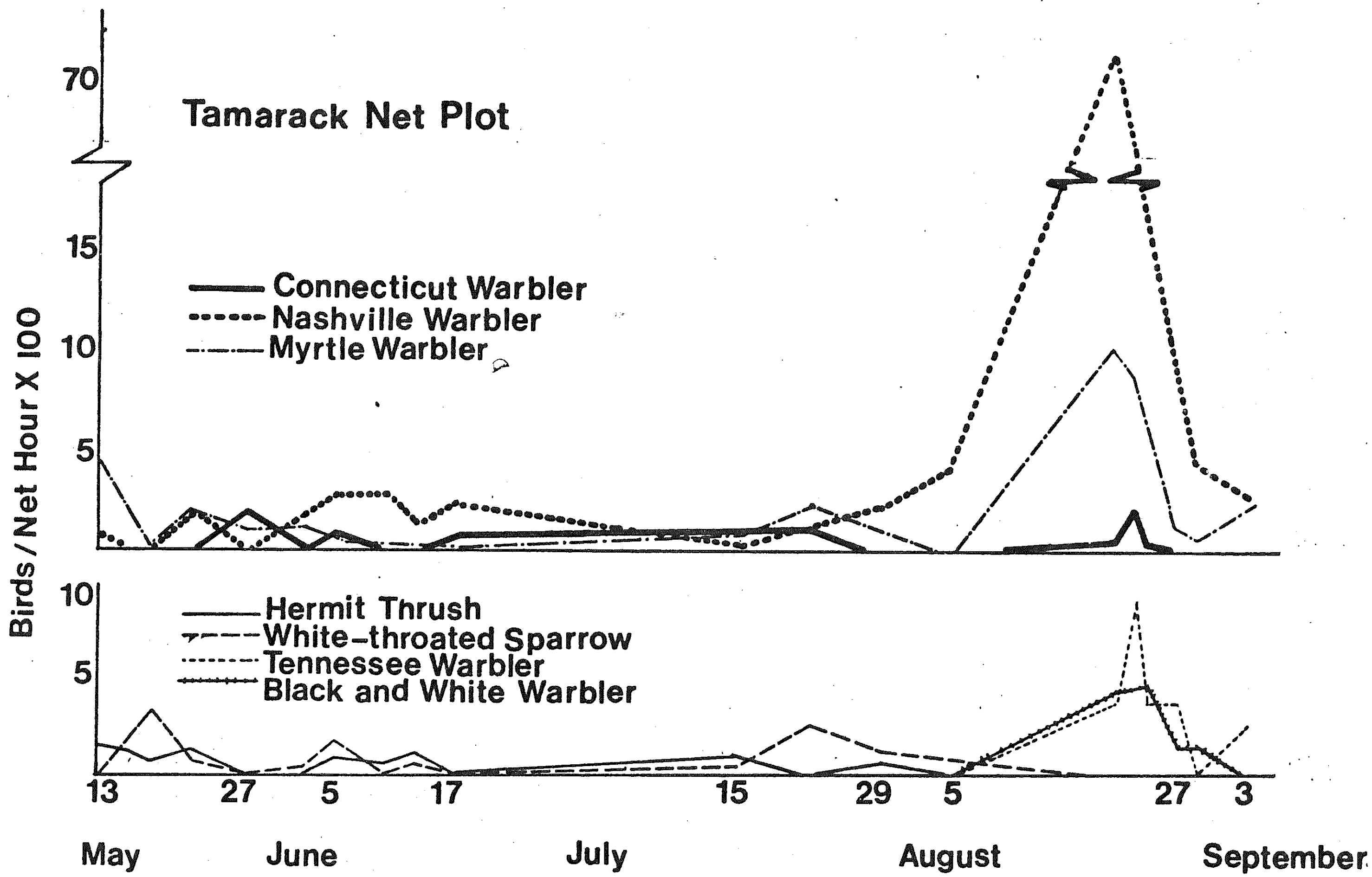


Figure 8. While all species maintained fairly low density levels through most of the season in the Spruce Conifer: Tamarack net plot, things changed drastically with the fall migration. The bulk of the migrating onrush was made up of Nashville, Myrtle, and Tennessee Warblers, the latter having been present only as a migrating species.

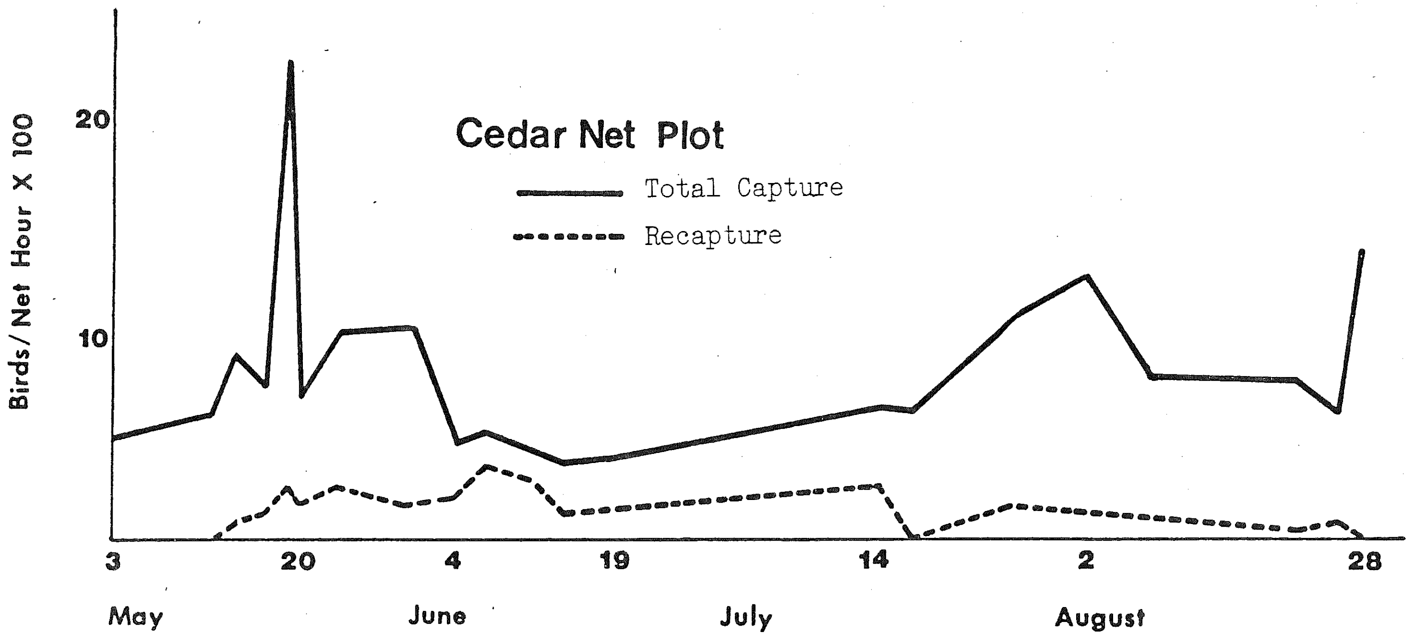


Figure 9. Similar peaks occurred in the volume of birds caught through the netting season in the Swamp Conifer: Cedar Spruce plot as in the other two plots. Fall migration was not nearly so dramatic here as in the Spruce Island or Tamarack.

The following three tables (see table 6, 7, and 8) depict capture dates in each of the three netting plots discussed above. An X indicates capture or recapture of at least one bird of that species on that date. Those species with x's across the board were commonly occurring resident species, while those at only one end of the line were either present only as migrating populations or occurred consistently in small numbers and simply weren't netted. Birds species are presented in the order in which they first appeared in the nets.

Table 6. SPRUCE ISLAND NET PLOT
BIRD SPECIES NETTED

	May								June									July							August										Sept.
	7	11	13	16	19	21	23	28	2	7	11	14	15	18	21	23	24	3	7	16	20	24	27	31	6	7	10	13	20	22	25	28	30	31	6
Palm Warbler	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Myrtle Warbler	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X		X		X	X		X	X	X	X	X	X	X
Hermit Thrush	X	X		X	X	X	X	X	X		X	X		X	X		X	X	X	X	X	X		X	X	X		X		X	X	X	X		X
Ruby-Cr. Kinglet		X	X	X	X		X	X	X	X	X											X	X	X											X
Orange-Cr. Warbler		X	X	X	X																														X
No. Waterthrush		X																														X	X		
Bl & Wh Warbler		X		X					X		X			X							X	X	X	X		X	X	X	X		X	X			X
Blackpoll Warbler		X				X	X	X																								X	X	X	
Chipping Sparrow		X																													X	X	X		X
Nashville Warbler			X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
Ovenbird			X		X														X												X	X			X
Wh.-Throated Spar.			X	X	X	X	X	X				X					X	X	X	X	X		X							X	X	X		X	
Bl.-Throat. Gr. Warb.			X			X																													
Lincoln's Sparrow				X			X								X				X	X	X			X	X	X		X	X		X	X			
Veery				X											X		X	X	X						X							X	X		
Swainson's Thrush					X														X	X											X	X	X		
Conn. Warbler					X																X				X			X		X		X			
Bay-Br. Warbler					X	X	X																							X	X	X	X	X	X
Least Flycatcher						X				X									X			X		X	X	X						X			X
Com. Yellowthroat						X														X						X			X						
Magnolia Warbler						X	X					X																			X				X
Yellow-Bel. Flyc.							X	X	X	X	X				X					X		X					X								
Chestnut-sided Warb.							X							X																					
Am. Redstart							X					X																X			X	X	X		X
Red-eyed Vireo							X												X										X		X				X
Brown-Head. Cowbird							X										X	X	X																
White-cr. Sparrow							X																												
Traill's Flycatcher								X	X			X					X		X							X		X			X	X			
Blackburn. Warbler								X																		X									
Blue Jay												X																							
Rose-br. Grosbeak												X																				X			
Gray Catbird																	X																		
Cedar Waxwing																	X																		
Savanna Sparrow																		X					X												
Clay-col. Sparrow																		X	X		X	X	X	X		X									
Black-billed Cuckoo																			X																
American Robin																			X					X		X						X			X
Amer. Goldfinch																			X																
Dark-eyed Junco																			X																
Song Sparrow																					X														
Yellow Warbler																						X		X											
Solitary Vireo																											X					X		X	X
Scarlet Tanager																									X										
Tennessee Warbler																												X			X	X	X		X

Table 6. (continued) SPRUCE ISLAND NET PLOT

	May								June									July							August										Sept.
	7	11	13	16	19	21	23	28	2	7	11	14	15	18	21	23	24	3	7	16	20	24	27	31	6	7	10	13	20	22	25	28	30	31	6
Downy Woodpecker																															X				
Eastern Phoebe																															X				
Brown Creeper																															X			X	
Cape May Warbler																															X	X	X	X	X
Red-Br. Nuthatch																																X		X	
Black Cap. Chickadee																																	X	X	X
Gray Cheeked Thrush																																	X		

Table 7. TAMARACK NET PLOT
BIRD SPECIES NETTED

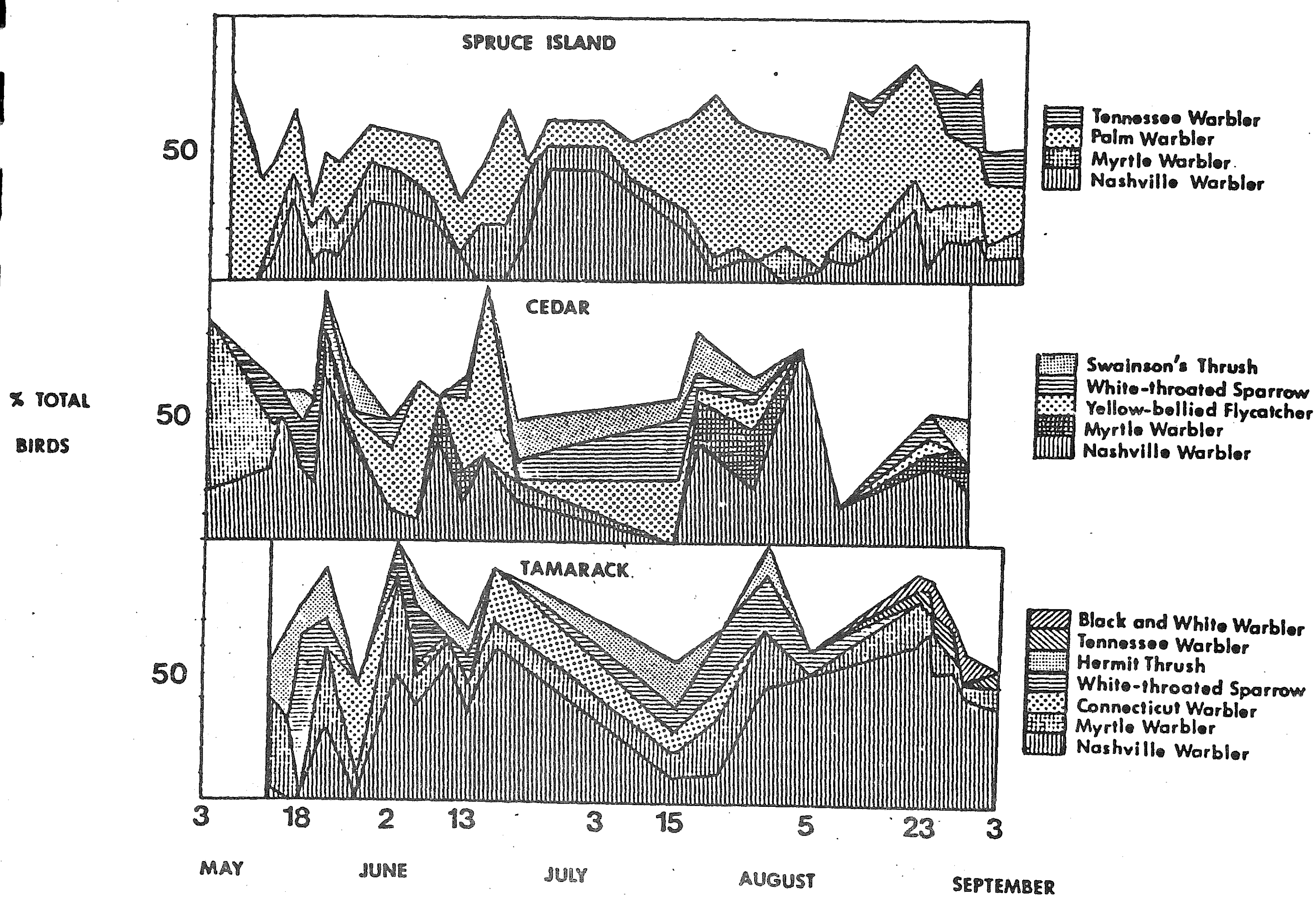
	May					June					July			August						
	13	16	18	22	27	2	5	10	13	17	15	22	29	5	21	23	24	27	29	3
Hermit Thrush	X	X		X	X		X	X	X		X		X							
Nashville Warbler	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Myrtle Warbler	X		X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X
Palm Warbler																	X		X	
Least Flycatcher		X																		
Blue Jay		X								X	X					X	X			
Black-capped Chick.		X		X			X	X						X		X		X	X	
White-thr. Sparrow			X	X	X	X	X		X		X	X	X	X						
Swainson's Thrush					X		X	X												
Veery					X															
Connecticut Warbler					X		X			X	X	X		X	X	X	X			
Yellowthroat					X										X		X			
Yellow-bel. Flycat.							X	X	X											
Traill's Flycatcher											X	X								
Red-br. Nuthatch											X									
Robin												X								
Dark-eyed Junco												X								
Gray Jay															X					
Red-eyed Vireo															X		X	X		X
Bl & Wh. Warbler															X	X	X	X	X	
Tennessee Warbler															X		X	X		X
Parula Warbler															X					
Bay-br. Warbler															X		X	X		
Ovenbird															X		X			
No. Waterthrush															X		X			X
Lincoln's Sparrow															X					
Magnolia Warbler																X		X		
Solitary Vireo																	X	X		X
Cape May Warbler																	X	X		
Blackburn. Warbler																	X	X		
Chipping Sparrow																	X			
Blackpoll Warbler																			X	X

Table 8. SWAMP CONIFER-CEDAR NET PLOT
BIRD SPECIES NETTED

Bird Species (in order of first appearance)	May 3	May 10	May 12	May 14	May 17	May 19	May 20	May 24	May 31	June 4	June 7	June 11	June 14	June 19	July 14	July 17	July 26	August 2	August 8	August 22	August 26	August 28
Ruby-cr. Kinglet	X			X				X						X								
Myrtle Warbler	X		X	X			X	X			X	X		X		X	X			X	X	X
Nashville Warbler	X		X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Gray Jay		X						X					X	X				X	X	X		X
Blue Jay	X	X	X																			
Winter Wren			X							X												
Magnolia Warbler			X						X													
Solitary Vireo			X					X	X		X						X			X		
White-thr. Sparrow			X	X	X	X	X		X			X		X	X	X	X			X		
Dark-eyed Junco				X	X			X	X	X	X	X			X			X	X		X	X
Bl. & Wh. Warbler					X				X					X	X		X	X	X			
Ovenbird					X	X										X	X		X			X
Swainson's Thrush				X	X			X		X	X			X	X	X	X				X	X
Hermit Thrush					X							X		X			X		X			X
American Redstart								X														
Yel-bellied Flycat.								X	X	X	X	X	X		X	X	X	X		X		
American Robin								X	X			X							X			
Red-Eyed Vireo									X										X	X	X	X
Wood Thrush									X													
Bl-back 3-toe Woodp.												X		X								
Purple Finch														X								
Red-br. Nuthatch															X	X						
Bl-Thr. Gr. Warbler																X		X				
Canada Warbler																X						
Brown Creeper																X			X			
Great-crested Flyc.																X						
Yellowthroat																	X					
Bl-capped Chickadee																	X	X	X			X
Least Flycatcher																	X					
Gold-wing Warbler																			X			
Rose-breast. Grosbeak																			X			
Tennessee Warbler																				X		
No. Waterthrush																				X	X	
Gold-crown. Kinglet																				X		
Traill's Flycatcher																				X		
Veery																						X
Palm Warbler																						X
Cape May Warbler																						X

There was a great deal of difference between the three net plots in vegetation structure and consequently, bird species composition. However, in all three areas the Nashville Warbler was one of the most important species (see fig. 10) throughout the season. The only other species that occurred in consistent significant percentages in all three areas was the Myrtle Warbler. Differences in the remaining species for each of the three habitats reflects the differences in habitat resources.

Fig. 10. Species by percent of total capture through time for each of the three net plots. Note that except for Nashville and Myrtle Warblers, the dominant species composition differs greatly between sites. Blank space represents all other species.



Projected Netting Plans

Another field season of continued netting would help confirm whether the trends suggested by this year's netting totals are actual annual patterns or not. Ideally, netting could be extended beyond September 6 (the date we stopped this year) to monitor more of the fall migration as well.

In addition to the three net plots now being studied, we would like to establish a new net plot in the vicinity of our Swamp Thicket transect. Censuses from 1978 show that this habitat is very rich in bird species density and diversity. Netting in the Swamp Thicket would be very valuable in offering a means for comparing the bird diversity in terms of netting results with the other net plots. It would also help in building a broader base for statistically relating bird population densities from transect censuses to densities found from netting.

Concluding Remarks

Before bird species can be quantitatively correlated to the vegetation along our transects, the data we have thus far collected must be analyzed by computer and our tree counts must be completed. At present it also appears that more census data will be necessary, and that will be added at the end of the coming field season. Otherwise our vegetation work is complete with the exception of the few remaining tree counts.

The results to date clearly indicate that the wetlands in the glacial Lake Agassiz basin have evolved and built up over the past 10,000 years to become a vast and varied complex of scattered peatland habitats, which have no similar counterpart of this magnitude elsewhere in the United States. Our investigations have already shown that the peat itself is a necessary and integral part of the life cycles of many bird species, such as those that reproduce and obtain food resources there, and stop in bog communities to molt and fatten up during migratory periods. Removal of the peat would mean direct removal of these species. "Rehabilitation" of these areas after peat removal would be virtually impossible, since once the peat is removed, different plants will move in and the habitat will have been changed.

The most significant conclusions at the present time in regard to the avifauna of the peatlands are that a game species, the Sharp-tailed Grouse, exists there in rather high numbers as a permanent breeding muskeg population; that other species such as the Palm Warbler are present as breeding species in specific habitats from early spring well into fall; and that other species utilize specific habitats very intensively for only brief periods of time. These findings, although preliminary in nature, show that these peatlands support a significant avifauna that merits further study.

Listing of Bird Species*

Botaurus lentiginosus (Rackett): American Bittern
Anas platyrhynchos (Linneaus): Mallard
Anas acuta Linnaeus: Pintail
Anas discors Linnaeus: Blue-Winged Teal
Aix sponsa (Linnaeus): Wood Duck
Mergus merganser Linnaeus: Common Merganser
Mergus serrator Linnaeus: Red Breasted Merganser
Buteo platypterus (Viellot) Broad Winged Hawk
Haliaeetus leucocephalus (Linnaeus): Bald Eagle
Circus cyaneus (Linnaeus): Marsh Hawk
Pandion haliaetus (Linnaeus): Osprey
Falco tinnunculus Linneaus: Kestrel
Canachites canadensis (Linnaeus): Spruce Grouse
Bonasa umbellus (Linnaeus): Ruffed Grouse
Pedioecetes phasianellus (Linnaeus): Sharp-tailed Grouse
Porzana carolina (Linnaeus): Sora
Coturnicops novaboracensis (Gmelin): Yellow Rail
Philohela minor (Gmelin): American Woodcock
Capella gallinago (Linnaeus): Common Snipe
Chlidonias niger (Linnaeus): Black Tern
Zenaidura macroura (Linnaeus): Mourning Dove
Coccyzus erythropthalmus (Wilson): Black-billed Cuckoo
Archilochus colubrins (Linnaeus): Ruby-throated Hummingbird
Megaceryle alcyon (Linnaeus): Belted Kingfisher
Colaptes auratus (Linnaeus): Common Flicker
Dryocopus pileatus (Linnaeus): Pileated Woodpecker
Sphyrapicus varius (Linnaeus): Yellow-bellied Sapsucker
Dendrocopos villosus (Linnaeus): Hairy Woodpecker
Dendrocopos pubescens (Linnaeus): Downy Woodpecker
Picoides articus (Swainson): Black-backed Three-toed Woodpecker
Tyrannus tyrannus (Linnaeus): Eastern Kingbird
Myiarchus crinitus (Linnaeus): Great Crested Flycatcher
Sayornis phoebe (Latham): Eastern Phoebe
Empidonax flaviventris (Baird and Baird): Yellow Bellied Flycathcer
Empidonax alnorum (Brewster): Traill's Flycatcher
Empidonax minimus (Baird and Baird): Least Flycathcer
Contopus virens (Linnaeus): Eastern Wood Pewee
Nuttallornis borealis (Swainson): Olive-Sided Flycatcher
Iridoprocne bicolor (Viellot): Tree Swallow
Hirundo rustica Linnaeus: Barn Swallow
Petrochelidon pyrrhonota (Vieillot): Cliff Swallow
Progne subis (Linnaeus): Purple Martin
Perisoreus canadensis (Linnaeus): Gray Jay
Cyanocitta cristata (Linnaeus): Blue Jay
Corvus corax Linnaeus: Common Raven
Corvus brachyrhynchos Brehm: Common Crow
Parus atricapillus Linneaus: Black-capped Chickadee
Parus hudsonicus Forster: Boreal Chickadee
Sitta carolinensis Latham: White-breasted Nuthatch
Sitta canadensis Linnaeus: Red-breasted Nuthatch
Certhia familiaris Linnaeus: Brown Creeper
Troglodytes aedon Vieillot: House Wren

Troglodytes troglodytes (Linnaeus): Winter Wren
Cistothorus platensis (Latham): Short-billed Marsh Wren
Dumetella carolinensis (Linnaeus): Catbird
Turdus migratorius Linnaeus: Robin
Hylocichla mustelina (Gmelin): Wood Thrush
Hylocichla guttata (Pallas): Hermit Thrush
Hylocichla ustulata (Nuttall): Swainson's Thrush
Hylocichla fuscescens (Stephens): Veery
Siala sialis (Linnaeus): Eastern Bluebird
Regulus satrapa Lichtenstein: Golden-crowned Kinglet
Regulus calendula (Linnaeus): Rusty-crowned Kinglet
Bombycilla cedrorum Vieillot: Cedar Waxwing
Vireo flavifrons Vieillot: Yellow-throated Vireo
Vireo solitarius (Wilson): Solitary Vireo
Vireo olivaceus (Linnaeus): Red-eyed Vireo
Vireo gilvus (Vieillot): Warbling Vireo
Mniotilta varia (Linnaeus): Black and White Warbler
Vermivora chrysoptera (Linnaeus): Golden-winged Warbler
Vermivora peregrina (Wilson): Tennessee Warbler
Vermivora celata (Say): Orange-crowned Warbler
Vermivora ruficapilla (Wilson): Nashville Warbler
Parula americana (Linnaeus): Parula Warbler
Dendroica petechia (Linnaeus): Yellow Warbler
Dendroica magnolia (Wilson): Magnolia Warbler
Dendroica tigrina (Gmelin): Cape May Warbler
Dendroica coronata (Linnaeus): Yellow Rumped Warbler
Dendroica virens (Gmelin): Black-throated Green Warbler
Dendroica fusca (Müller): Blackburnian Warbler
Dendroica pensylvanica (Linnaeus): Chestnut-sided Warbler
Dendroica castanea (Wilson): Bay-breasted Warbler
Dendroica striata (Forster): Blackpoll Warbler
Dendroica pinus (Wilson): Pine Warbler
Dendroica palmarum (Gmelin): Palm Warbler
Seiurus aurocapillus (Linnaeus): Ovenbird
Seiurus noveboracensis (Gmelin): Northern Waterthrush
Oporornis agilis (Wilson): Connecticut Warbler
Oporornis philadelphia (Wilson): Mourning Warbler
Geothlypis trichas (Linnaeus): Yellowthroat
Wilsonia pusilla (Wilson): Wilson's Warbler
Wilsonia canadensis (Linnaeus): Canada Warbler
Setophaga ruticilla (Linnaeus): American Redstart
Dolichonyx oryzivorus (Linnaeus): Bobolink
Sturnella magna (Linnaeus): Eastern Meadowlark
Xanthocephalus xanthocephalus (Bonaparte): Yellow-headed Blackbird
Agelaius phoenicius (Linnaeus): Red-winged Blackbird
Icterus galbula (Linnaeus): Northern Oriole
Euphagus carolinus (Müller): Rusty Blackbird
Euphagus cyanocephalus (Wagler): Brewer's Blackbird
Quiscalus quiscula (Linnaeus): Common Grackle
Molothrus ater (Boddaert): Brown-headed Cowbird
Piranga olivacea (Gmelin): Scarlet Tanager
Pheucticus ludovicianus (Linnaeus): Rose-breasted Grosbeak
Passerina cyanea (Linnaeus): Indigo Bunting
Carpodacus purpureus (Gmelin): Purple Finch
Spinus pinus (Wilson): Pine Siskin

Spinus tristis (Linnaeus): American Goldfinch
Loxia curvirostra Linnaeus: Red Crossbill
Passerculus sardwichensis (Gmelin): Savannah Sparrow
Ammospiza leconteii (Audubon): LeConte's Sparrow
Ammospiza caudacuta (Gmelin): Sharp-tailed Sparrow
Junco hyemalis (Linnaeus): Dark-eyed Junco
Spizella passerina (Bechstein): Chipping Sparrow
Spizella pallida (Swainson): Clay-colored Sparrow
Zonotrichia albicolis (Gmelin): White-throated Sparrow
Melospiza lincolnii (Audubon): Lincoln's Sparrow
Melospiza georgiana (Latham): Swamp Sparrow
Melospiza melodia (Wilson): Song Sparrow

* according to A.O.U., 1957 and supplement.

Literature Cited

American Ornithologists' Union. 1957. Checklist of North American Birds. Lord Baltimore Press, Baltimore. 691 pp.

__________. 1973. Thirty-second Supplement to the American Ornithologists' Union Checklist of North American Birds. The Auk. 90(2):411-419.

Braun-Blanquet, J. 1932. Plant Sociology. McGraw-Hill Co. New York. xviii + 439 pp.

Fox, R., T. Malterer, and R. Zarth. 1977. Inventory of Peat Resources in Minnesota, State of Minnesota, Department of Natural Resources, Division of Minerals, Progress Report, 35 pp.

Heinselman, M. L. 1970. Landscape Evolution, Peatland Types and the Environment in the Lake Agassiz Peatlands Natural Area, Minnesota. Ecology 40: 235-61.

James, F. C. and H. H. Shugart, Jr. 1970. A Quantitative Method of Habitat Description. Audubon Field Notes. 24(6): 727-734.

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

Küchler, A. W. 1967. Vegetation Mapping. Ronald Press Co. New York. 472 pp.

MacArthur, R. H. and J. W. MacArthur. 1961. On Species Diversity. Ecology. 42(3):594-598.

Willson, M. F. 1974. Avian Community Organization and Habitat Structure. Ecology. 55:1017-1029.

SECTION D

UTILIZATION OF MINNESOTA PEATLAND HABITATS BY LARGE MAMMALS AND BIRDS

A Preliminary Report Submitted to
The Minnesota Department of Natural Resources

December, 1978

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SUMMARY

In a four-square mile area of Hubbard County, Minnesota, radiotelemetry has been used to study habitat use and selection by spruce grouse, ruffed grouse, showshoe hare, and whitetail deer. The study area selected contained a mixture of three upland and six lowland habitat types so that special attention could be given to selection for or against various kinds of peatlands. To date, we have successfully monitored 16 snowshoe hare, two whitetail deer, eight spruce grouse, and five ruffed grouse.

Preliminary results indicated that individual snowshoe hare varied considerably in patterns of habitat use, but almost always showed selection for alder fen. More than half of the hares selected for black spruce-tamarack bog, while one-fourth showed selection for mixed uplands. Snow track surveys and a pellet count conducted in the study area further emphasized the primary importance of alder, and the high utilization of coniferous lowlands.

Radio-tagged spruce grouse were found exclusively in jack pine through most of winter. Adult males apparently sought display territories in black spruce-tamarack bog by late March, and remained in these coniferous lowlands through summer. Females showed strong selection for black spruce-tamarack bogs in the month before incubation began. In at least two cases, nesting and brood rearing occurred almost exclusively in jack pine, with some use made of jack pine clearings. During the summer and early fall, there was selection for both jack pine and black spruce-tamarack bog. By late fall, when show covered the ground, all radio-tagged spruce grouse were back in jack pine.

Radio-tagged ruffed grouse showed a wide variety of habitat use patterns; only alder and jack pine were used to any extent by all males and females. Females selected for alder and no other type. Two males showed selection for alder through all seasons observed, and one selected for mixed upland throughout that time. One male apparently favored mixed upland only in the spring and summer months, while another selected for black spruce-tamarack bog in spring and summer. Although no males showed strong selection for jack pine, all three more than doubled their use of this type in fall.

Whitetail deer appeared to be strongly individualistic in habitat utilization patterns. One yearling female was found primarily in jack pine in all seasons, but showed selection for alder and black spruce-tamarack bog from April through September. An adult doe, with fawn, on the other hand, appeared to use primarily mixed upland and jack pine habitats in all seasons.

INTRODUCTION

Minnesota contains vast areas of peatlands, yet until recently, very little effort had been made to understand certain aspects of their ecology. Vitrually nothing was known about the use of these peatlands by terrestrial vertebrates. The primary purpose of this study has been to investigate peatland use and selection by four game species: spruce grouse, ruffed grouse, showshoe hare, and whitetail deer.

Using radio-telemetry in an area containing a mixture of upland and lowland habitats, we wished to determine

(1) What types of peatlands are used by each of these species, and to what extent;

(2) Which habitats are selected for or against (i.e., used disproportionately to their availability);

(3) What changes in use and selection occur in various seasons and in various times of night and day; and

(4) For what activities do these species use each habitat type in which they are found?

METHODS

The study area selected for this project includes most of Sections 6 and 7 of Lake George Township, and Sections 1 and 12 of Lake Alice Township in Hubbard County, Minnesota. The area is largely jack pine upland interspersed with several types of lowlands, such as tamarack and black spruce bog, sedge fen, alder, and scrub fen. A complete list of habitat types and their availability can be found in Appendix A.

Data were collected for this study primarily by the use of high-frequency radio-tracking system. Animals were trapped, radio-tagged, and released within the study area, and then were relocated at least once in every 48-hour period. The time schedule for relocation was varied as much as possible in an attempt to obtain data from different periods of day and night.

Locations were made most often by triangulating from known positions using hand-held antennas or antennas that were mounted on 25-foot towers. For each triangulation, bearings were recorded in compass degrees from three or more positions. These bearings were plotted on a gridded vegetation map to find the point of intersection and the corresponding x, y coordinates. The data, time, habitat type, and x, y coordinates were recorded for each location of each animal.

Visual locations were also made, since direct observation was often the only means of obtaining data on nesting, displaying, and other important activities. To make such locations we followed the appropriate radio signal until the animal was in sight. The distance from the point of observation to a known location was paced on a specified compass bearing. This information was then plotted on the vegetation map to determine the x, y coordinates corresponding to the animal's position.

When analyzing radio-telemetry data, it was assumed that the distribution of radio locations in various habitats reflected the actual distribution of use of those habitats. Thus, if 10 percent of an animal's locations were in alder, it was assumed that the animal actually used alder about 10 percent of the time.

In conjunction with radio-telemetry work, weather data were collected on a daily basis. These included temperature, precipitation, wind direction, and wind speed. Maximum and minimum daily temperatures were available from the Lake Itasca Biology Station. During periods of snow cover, snow depths and profile information were gathered weekly in six different habitat types.

Additional sources of information on habitat use and selection included snow track surveys in periods of adequate snow cover, a pellet survey in the spring, and road track censuses in the summer and early fall.

Snow track surveys were made after each fresh snowfall from February through April, 1978. They were reinitiated in November, 1978, with the intention of continuing these surveys through the 1978-1979 winter. In each survey eleven habitats were sampled for tracks, droppings, and other sign of deer, hare, and grouse. Within each habitat type the worker walked a specified number of paces and then stopped, examining the circular area ten feet in all directions for the presence or absence of various types of animal signs. This procedure was repeated until a designated number of circular plots had been checked. The number of plots examined in each type was made roughly proportional to the amount of that type within the study area.

The pellet survey was conducted in the spring, to correspond with DNR pellet surveys of other areas. For our work ten habitats were sampled using 30 randomly chosen rectangular plots, 10 ft. x 6 ft., in each type. In each plot the number of deer pellet groups was counted and the presence or absence of hare and grouse droppings were noted. Plot sample sizes were not skewed to habitat availability in this case, because the survey was done in conjunction with a similar survey in the Red Lake Peatlands of Beltrami County. An attempt was made to compare the use of comparable habitat types in the two areas.

On the unpaved road bisecting the study site, we undertook a census of deer tracks after each heavy rainfall and after each road grading in summer and early fall. Along this two-mile stretch of road, we recorded the habitat type from which each set of tracks emerged onto the road and the type it entered upon leaving the road. The total numbers of tracks entering or exiting each habitat type were then compared to the percentages of each type that bordered the road.

Incidental information on all four species has been gathered by recording sightings and signs of unmarked animals encountered during routine field work. These data, tabulated according to habitat types, are of great interest despite the fact that they cannot be submitted to statistical testing.

All other forms of data discussed above have been or will be statistically analyzed. The chi-square goodness of fitness test has proved to be the most useful analytical tool thus far. We have used the Freeman-Tukey modification of the chi-square test in most of our work, because its variance-stabilizing properties seem to yield more reasonable analyses when sample sizes are small (Bishop, Fienberg, and Holland 1975).

Radio-telemetry data on snowshoe hares have been analyzed separately for each individual. At least three methods of evaluating habitat selection have been or will be used. In each case, the number of locations in each habitat type is compared to the number expected in that type if the animal moved at random through the "available" area (i.e., was found in each type in proportion to that type's availability). In most literature on this subject, "available" habitat is considered to be anything within the minimum area home range polygon, as described by Mohr (1947). We are experimenting with two other means of determining availability. One involves calculating an activity center by averaging all the x coordinates and y coordinates corresponding to animal locations. Then a circle is drawn with a radius equal to the distance between the activity center and the radio-location furthest from it. The second method we are trying involves using the area of the entire study site. Proportions of each habitat type within the polygon, the circle, or the study site were considered the proportions available to the animal. Chi-square tests were used to determine whether the animal was selecting for or against certain habitats or whether it was moving at random throughout what was available.

Graphs were made to show which habitats were selected for or against, and how strongly. Following the method of Berg and Philips (1973) the graphs display the differences between the percent of locations in a given habitat and the percent of that habitat that was available.

In addition to examination of all the data on each hare, night and day locations were separated and analyzed for statistical differences.

Further work on possible time period differences and seasonal differences will be completed in the future.

Spruce grouse and ruffed grouse data were analyzed on an individual basis using the same procedures described for hares, considering the entire study site as the area available. Seasonal patterns of habitat selection were analyzed separately for females and males.

Data on one of the radio-tagged deer have been analyzed for seasonal and for day/night patterns of habitat use. As with the grouse, the proportions of each habitat in the study site were considered the proportions available to the animal.

RESULTS

SNOWSHOE HARES: The present analyses involve data for eight of twelve radio-tagged hares that are no longer on the radio-tracking system. Another eight hares are currently being monitored and data on their locations will be analyzed when field work is concluded.

Before statistical analyses of habitat use and selection could be done, location data had to be examined for differences in day/night use and in seasonal patterns of use. Preliminary analyses show no strong patterns for seasons or for day and night among the animals examined. Further work will be done in this area, however, since some sample sizes (e.g., night locations) were still smaller than desirable for statistical testing.

Home ranges of these animals varied from 5 to 15 acres, with an average of 10.5 acres. Complete home range and movement data will be presented in the final report, along with analyses of seasonal patterns of movement.

Data on habitat use are presented in Table 1, expressed as percentages of radio-telemetry locations attributed to each habitat type for each of eight hares. For three of these animals, the greatest number of locations were made in black spruce-tamarack bogs and the second greatest number were in alder. For three other hares, alder received the most use while jack pine ranked second. In one case mixed upland ranked first, followed by black spruce-tamarack bog; and for another hare, jack pine was used most often, followed by alder.

Obviously, combining data for hares with this much individual variation would be useless for examining use and selection by hares in general. As a consequence of this, statistical tests were done separately for each hare.

Table 1. Habitat use by eight snowshoe hare in the Lake Alice study area expressed as a percent of the total radio-telemetry locations for each individual, January to November 1978.

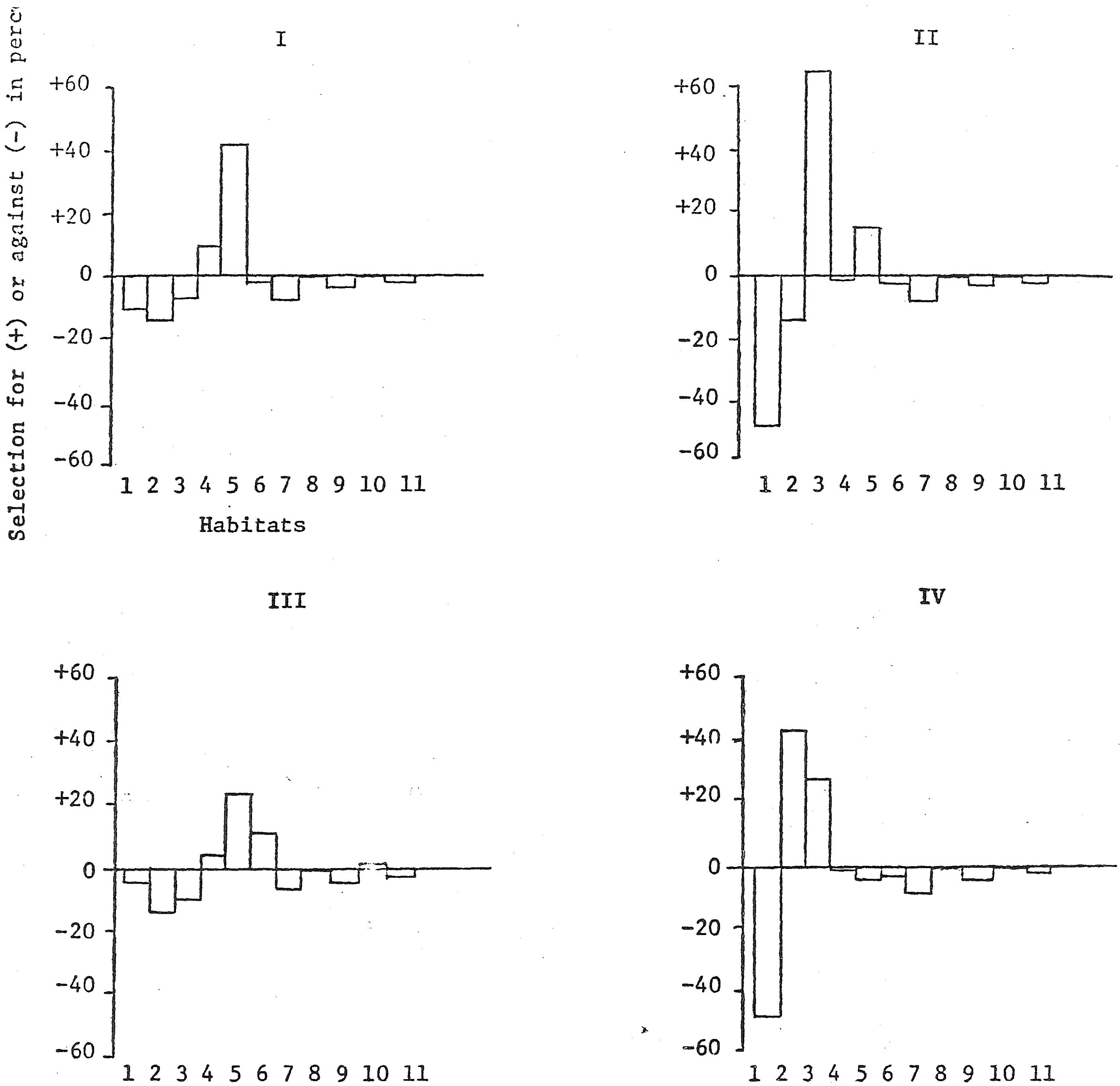
Habitat types	Hares 108b	428a	455	492a	492b	648	884	920
Jack pine	41.2	4.0	46.8	3.3	17.7	16.7	10.7	20.2
Mixed upland	0	0	0	56.7	0	0	0	.9
Black spruce-tamarack bog	2.6	75.0	0	36.7	41.9	58.3	3.6	0
Muskeg	10.5	0	4.8	0	0	0	0	0
Alder fen	44.4	21.0	30.1	3.3	40.3	25.0	85.7	78.1
Scrub fen	1.3	0	14.3	0	0	0	0	0
Sedge fen	0	0	2.4	0	0	0	0	.9
Open bog	0	0	0	0	0	0	0	0
Upland Clearing	0	0	0	0	0	0	0	0
Unpaved road	0	0	1.6	0	0	0	0	0
Open water	0	0	0	0	0	0	0	0
Total number observations:	39	50	21	15	31	12	28	57

Tests for habitat selection (using total study site percentages as being available) resulted in seven of the eight hares showing significant selection ($p < .05$). For the hare for which selection could not be demonstrated, it appears that the exceedingly small sample size was responsible for the test result.

Figure 1 graphically shows selection for or against each habitat type, expressed as the difference between the percent of habitat available and the percent of radio-locations in each type. In seven cases selection was shown for alder, in four cases for black spruce-tamarack bog, in two cases for muskeg, in one case for mixed upland and or scrub fen, and in no case for jack pine, sedge fen, open bog, upland clearing, the unpaved road, and open water.

Table 2 presents the cumulative results of five snow track surveys. Hare tracks were present most often in alder plots (68% occurrence), with more than 50% presence of tracks also occurring in intermediate-sized tamarack, and young or stunted tamarack and black spruce stands. Mature black spruce-tamarack bog and jack pine ranked as intermediate in percent occurrence (39% and 35%, respectively). Sedge fen, open bog, and upland clearing all had less than 10% occurrence of tracks. Droppings were distributed in much the same way with highest presence (20% or more) in alder, intermediate tamarack, and young or stunted tamarack. Hare forms were rarely found, but had the highest occurrence in alder fen (8%). The distributions of hare tracks, droppings, and forms were all found to be significantly different from random.

Table 3 presents the results of the pellet survey. Again, the habitat with the highest proportion of plots containing droppings was alder (97%).



Habitats: 1. Jack pine
2. Mixed upland
3. Black spruce-tamarack bog
4. Muskeg
5. Alder fen
6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

Figure 1. Selection by 8 snowshoe hares in the Lake Alice study area for (+) or against (-) habitat types, expressed as the difference between the percent of habitat available and the percent of radio-telemetry locations in each type, January to November 1978. I. Hare 108b, II. Hare 428a, III. Hare 455, IV. Hare 492a, V. Hare 492b, VI. Hare 648, VII Hare 884, VIII Hare 920.

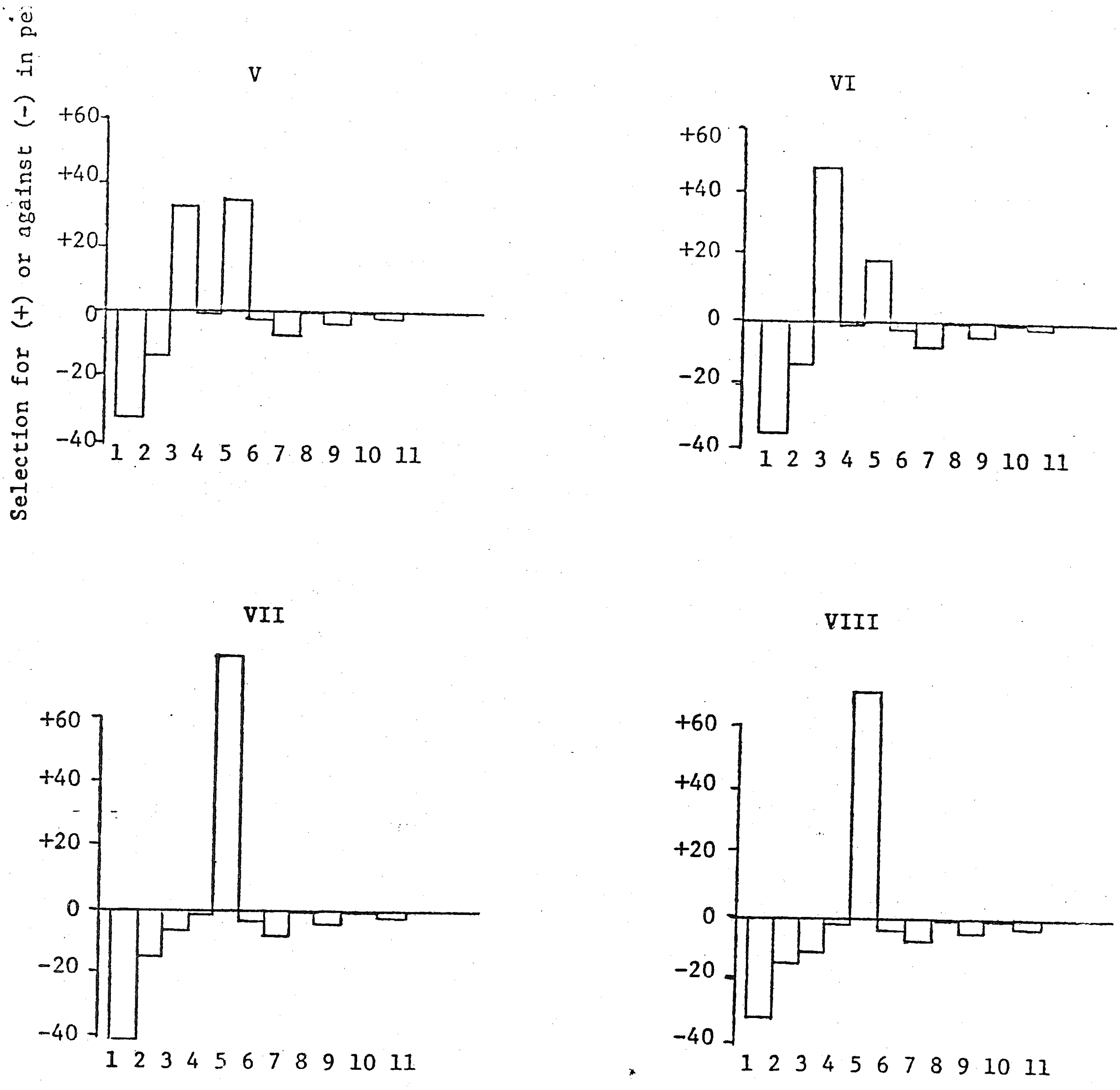


Figure 1. Continued.

Table 2. Habitat use by snowshoe hare and whitetail deer as evidenced by five snow track surveys (Feb., Mar., Apr., and Nov. 1978) in the Lake Alice study area. Numbers represent the percent of the sample plots in each habitat in which sign was present.

Habitat type	Deer tracks: % plots in which present	Hare tracks: % plots	Hare droppings: % plots	Hare forms: % plots	Total # plots sampled
Jack pine	7.0	35.0	10.2	3.2	500
Deciduous upland	8.0	31.0	5.0	0	100
Mature Black spruce - tamarack bog	0	38.6	1.4	0	70
Intermediate Black spruce (open under-story)	1.9	20.4**	3.7	1.9	54
Intermediate tamarack	10.0*	60.0	22.0	3.0	100
Young or stunted black spruce	4.0*	60.0	12.0	2.0	50
Young or stunted tamarack	0	62.0	26.0	2.0	50
Alder fen	2.7	68.0	26.7	8.0	150
Sedge fen	2.0	0	0	0	100
Open bog	0	5.6	1.1	0	90
Upland clearing	8.0	8.0**	4.0*	1.0*	100
Total # plots in which sign was present	70	480	141	35	

* all in the November sample

** largely in the November sample

Table 3. Habitat use by whitetail deer, snowshoe hare, and grouse as evidenced by a pellet survey in the Lake Alice study area, May 1978. For whitetail deer and for grouse the numbers represent the total number of pellet groups found in 30 sample plots (10 ft x 6 ft). For snowshoe hare the numbers represent the number of the 30 plots in which hare droppings were present.

	DEER: # pellet grps. found	HARE: # plots in which droppings were found	GROUSE: # droppings found
Jack pine	19	17	1 (spruce grouse)
Deciduous upland	21	8	0
Mature black spruce bog	1	25	0
Mature tamarack bog	0	11	0
Intermediate black spruce tamarack	0	14	0
Stunted tamarack-muskeg	0	6	0
Alder	1	29	2 (ruffed grouse)
Scrub fen	0	2	0
Sedge fen	0	0	0
Open bog	0	0	0
Total (for 300 plots)	42	112	1 spruce 2 ruffed

Table 4. Habitat use by male and female spruce grouse in the Lake Alice study area, expressed as a percent of the total radio-telemetry locations for each specified period. For females these periods are: snowcover, 10 Feb. - 15 Apr.; pre-nesting, 16 Apr. - 17 May; incubation and with clutchings, 18 May - 27 June, and post-clutchling, 28 June - 31 Oct. 1978. For males these are: winter, Jan - mid Mar., and spring - fall, mid Mar. - mid Oct. 1978.

	Spruce grouse					
	Females				Males	
Habitat types	snow cover	pre-nesting	incubating and with clutchlings	Post-clutchling	Winter	Spring-Fall
Jack pine	100.0	49.2	89.5	64.1	95.3	1.7
Mixed upland	0	0	0	0	0	0
Black spruce-tamarack	0	47.9	0	21.1	4.7	83.5
Muskeg	0	0	0	0	0	0
Alder fen	0	2.9	0	8.5	0	14.8
Scrub fen	0	0	0	1.9	0	0
Sedge fen	0	0	0	1.5	0	0
Open bog	0	0	0	0	0	0
Upland Clearing	0	0	10.5	3.0	0	0
Unpaved road	0	0	0	0	0	0
Open water	0	0	0	0	0	0
Total # obs.:	78	41	43	135	43	88
# individuals pooled:	3	3	2	3	3	1

Mature black spruce bog ranked a close second (83%), while jack pine and intermediate black spruce-tamarack bog held intermediate positions (57% and 47%, respectively). No droppings were found in sedge fen or open bog.

In the course of field work, 90 incidental observations of unmarked hares have been made to date (see Appendix B)*. Although we spent considerably more time walking through jack pine than through other habitat types, only 22% of the hare observations were in jack pine. The largest numbers were seen in alder and in mixed upland. None were reported in upland clearings, muskeg, or ppen bog.

SPRUCE GROUSE: Of ten spruce grouse that have been radio-tagged this year, eight have sufficient data for analysis, and three are still being monitored. Partial data on seven of these birds has been included in this presentation.

Home range and movement data have been examined for two nesting hens and one breeding male thus far. These data show strong seasonal shifts in home range and in length of movements for both sexes. Presentation of this information and similar work on other spruce grouse will be given in the final report.

The percents of radio-telemetry locations attributed to each habitat type are shown in Table 4 for males and females. Habitat use patterns were so similar for the females that data were combined for each season. However, seasonal differences were so strong that four separate blocks of time had to be recognized for purposes of analysis.

During the period of snow cover all locations on female spruce grouse were in jack pine. During the month prior to incubation, when females were apparently seeking mates and laying eggs, these females utilized jack pine and black spruce-tamarack bog in almost equal proportions.

While incubating and with clutchlings* the two hens who nested on the study site were found 90% of the time in jack pine (each nested at the base of a jack pine) and 10% in adjacent upland clearings. A third radio-tagged hen nested off the study area and could not be located during most of this period. However, from the few long distance radio-locations that were obtained, it appears that she may have nested in a tamarack bog.

In the period after the young were able to fly, jack pine was still used extensively by the two hens on the study site, but considerable time was spent in tamarack-black spruce bog and in alder as well. The third female with young was located in a tamarack-alder bog through much of this period. The latest fall locations (since snow fell) place all three hens back in jack pine.

Figure 2 shows habitat selection by females to be strongest for jack pine during snow cover and incubation periods, and strongest for black spruce-tamarack bog during the pre-nesting period. In the post-clutchling period there was selection for both jack pine and black spruce-tamarack bog. In all four periods statistical analysis showed the occurrence of significant habitat selection.

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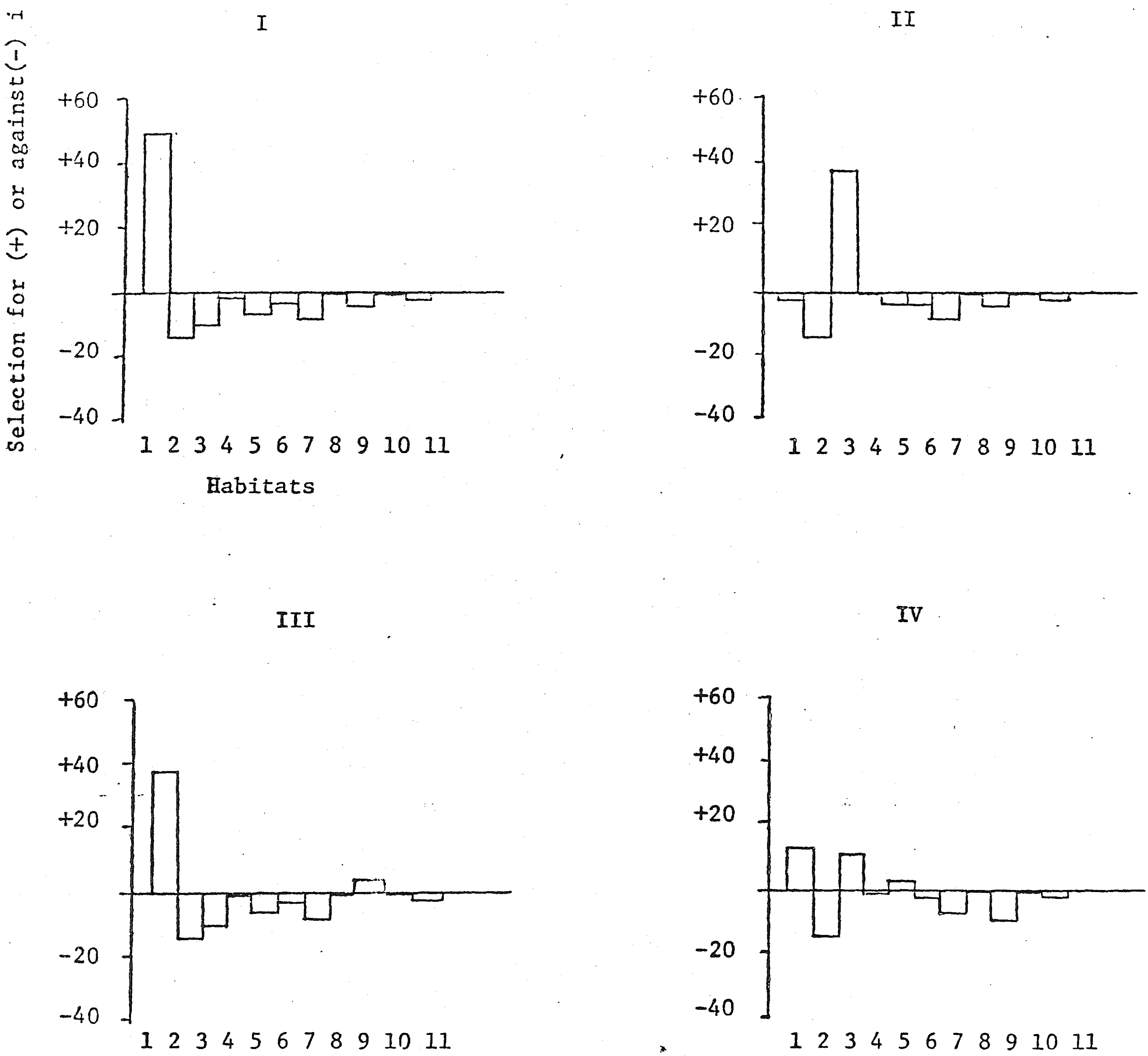
*clutchlings is applied to chicks in their first two weeks of life, before they are capable of flight (Leopold 1933)



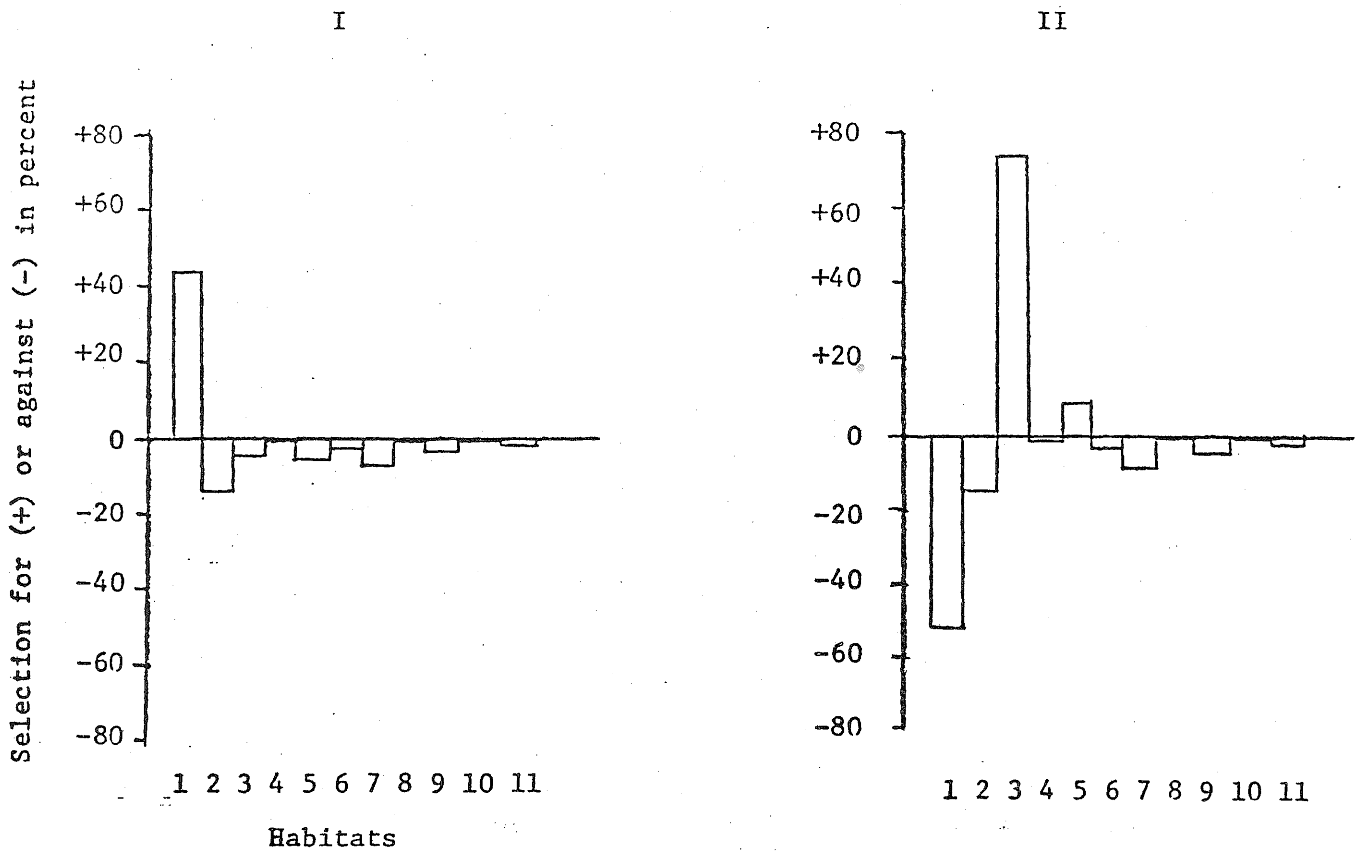
Habitats:
1. Jack pine
2. Mixed upland
3. Black spruce-tamarack bog
4. Muskeg
5. Alder fen
6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

Figure 2. Selection by female spruce grouse in the Lake Alice study area for (+) or against (-) habitat types, expressed as the difference between the percent of habitat available and the percent of radio-telemetry locations in each type. I. Snow cover (10 Feb.- 15 Apr. 1978), II. Pre-nesting (16 Apr.- 17 May 1978), III. Incubating and with clutchlings (18 May-27 June 1978), IV. Post-clutchling (28 June - 31 Oct. 1978).

Male spruce grouse, also shown in Table 4, used jack pine almost exclusively during the winter. After mid-March one of the males restricted his movements almost entirely to an area of black spruce-tamarack bog, where he was observed giving an aggressive display on numerous occasions. Another male dispersed off of the study site into similar bog habitat, but could not be found by late March. Still another male moved extensively in jack pine and bog habitats until it was lost completely in June; this bird apparently did not have a display territory and thus was probably a non-breeder.

Habitat selection, as shown in Figure 3, was obviously for jack pine in the winter for all the radio-tagged males. In spring, summer, and early fall black spruce-tamarack bog was strongly selected for by the one male that was known to have held a display territory. Alder, which occurred in patches within and at the edge of the bog, was selected for to a lesser extent. Statistical analyses showed significant habitat selection by grouse for both periods.

Snow track and pellet count surveys were not useful for obtaining information on spruce grouse. Incidental sightings of unmarked birds totaled 174, most of which were groups of birds seen in jack pine during winter (116). In snowless months most were seen in jack pine (33) and in black spruce-tamarack bogs (22). Unfortunately, the difference in visibility between these two habitat types is very great; the probability of seeing a bird in jack pine is much higher than that of seeing one in coniferous bogs. As a result, these data must be viewed with some skepticism.



Habitats:
1. Jack pine
2. Mixed upland
3. Black spruce-tamarack bog
4. Muskeg
5. Alder fen
6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

Figure 3. Selection by male spruce grouse in the Lake Alice study area for (+) and against (-) habitat types, expressed as the difference between the percent of habitat available and the percent of radio-telemetry locations in each type. I. Winter (Jan.-mid. March 1978), II. Spring-Fall (mid March- mid Oct. 1978).

Summer observations made on feeding behavior of a hen and her offspring produced a list of foods that were eaten during this period. The observer saw blueberry leaves and fruits eaten most often, but other foods noted include northern bedstraw, vetch, wild pea, cow-wheat, raspberry, tamarack, snowberry, grass, mushrooms, and insects.

Prior to 1 May 1978, most grouse were seen in trees where they were occasionally observed eating conifer needles. After 1 May, they were found more often on the ground feeding on herbs and shrubs.

RUFFED GROUSE: Of six ruffed grouse that have been radio-tagged during this study, three are currently being monitored. Five of the six had sufficient data to be included in the present analysis.

Home range and movement data have not been examined for all seasons. This information will be available in the final report.

Table 5 presents the percentages of radio-locations made in each habitat type for each of five ruffed grouse. Though apparently similar in their habitat use, the two females were analyzed separately since one nested successfully and the other did not. The successful hen nested at the base of an alder clump. She was found primarily in alder and secondarily in jack pine until 7 July when she was killed by a predator. The other female was found nesting in late June (probably a renest) at the base of a large jack pine. After her eggs disappeared, she moved to an alder hollow and subsequently to areas of jack pine mixed with other upland conifers.

Table 5. Habitat use by male and female ruffed grouse in the Lake Alice study area, expressed as a percent of the total radio-telemetry locations for each specified period, 1978.

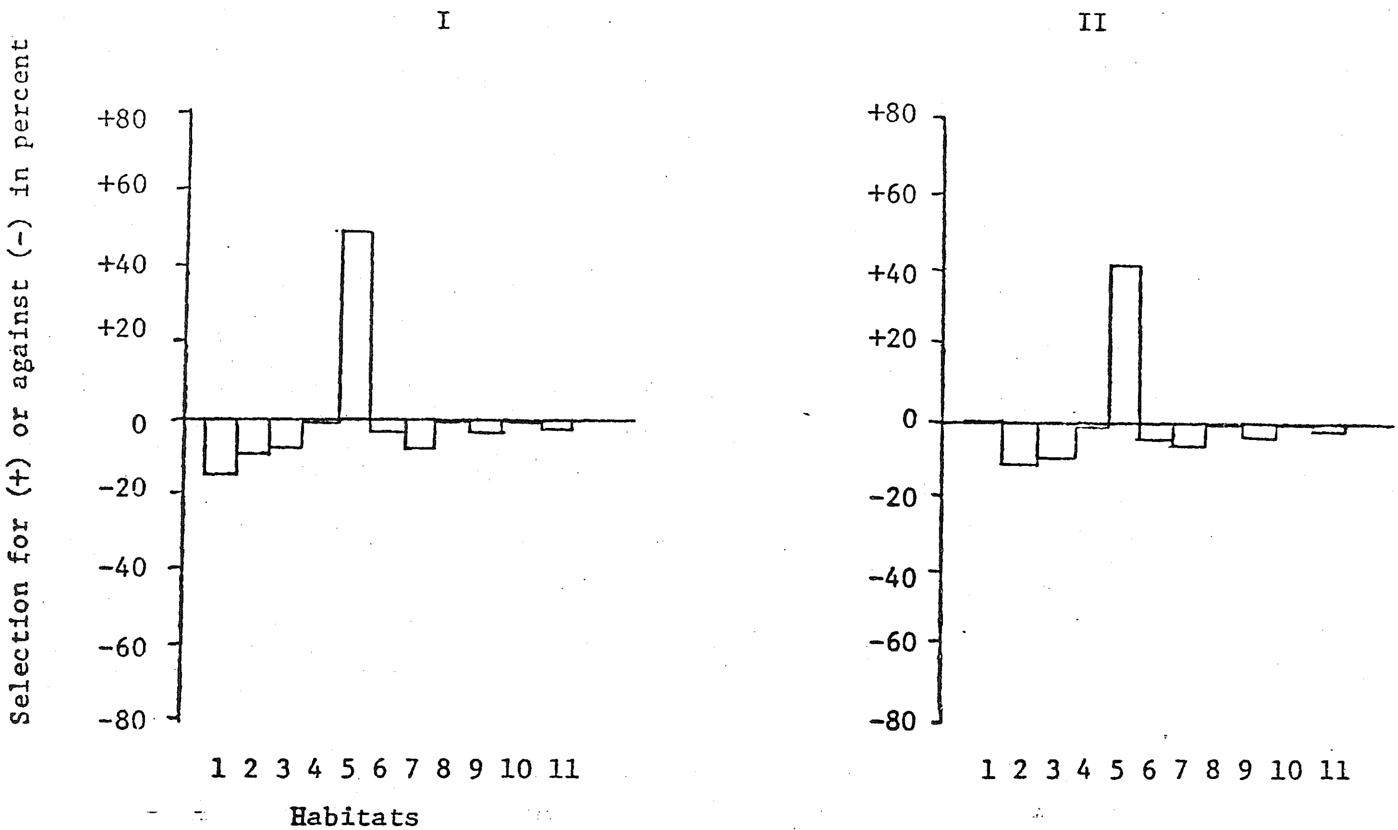
	Females		Males								
	395:	567:	304			355			538		
Habitat type:	nesting and with young	nesting and post - nest predation	May-June	July-Aug.	Sept.-Oct.	May-June	July-Aug.	Sept.-Oct.	May-June	July-Aug.	Sept.-Oct.
Jack pine	36.7	51.6	6.5	9.4	18.5	16.2	14.1	41.1	18.8	14.1	51.7
Mixed upland	5.0	3.1	80.4	84.4	75.8	43.3	48.4	16.7	0	0	0
Black spruce-tamarack	0	0	0	3.1	4.0	3.7	7.8	0	33.3	38.6	5.0
Muskeg	0	0	0	0	0	11.8	4.7	5.0	0	0	0
Alder fen	56.7	42.2	8.7	0	0	25.0	25.0	28.3	47.9	43.8	30.0
Scrub fen	0	0	0	0	0	0	0	3.3	0	0	0
Sedge fen	1.7	0	0	0	0	0	0	4.2	0	0	0
Open bog	0	0	0	0	0	0	0	0	0	0	0
Upland Clearing	0	3.1	0	3.1	1.6	0	0	0	0	0	13.3
Unpaved road	0	0	0	0	0	0	0	0	0	0	0
Open water	0	0	0	0	0	0	0	0	0	0	0
Total # observations:	20	32	23	32	31	36	32	30	24	32	30

Figure 4 shows that both hens selected for only habitat type: alder. All other types were used in proportion to their availability or somewhat less. This pattern of habitat selection was found to be statistically significant.

The three ruffed grouse males that were radio-tagged were captured on drumming logs in late April and early May, 1978. Differences in habitat use patterns among these males required that they be analyzed separately. In addition, three possible seasonal shifts were noted in at least one of the birds, so data for each male were segregated into three time blocks. Male 538 was found most often in alder in spring and summer, with black spruce-tamarack bog ranking a close second. Jack pine was third in both periods, and no other types were disproportionally chosen. In fall, however, there was a shift to greater use of jack pine, which suddenly became the type in which the bird was most often located. Black spruce-tamarack bog utilization fell sharply, while upland clearings suddenly gained significance.

In the spring and summer months, male 355 was found most often in mixed upland, was found secondly in alder, and thirdly in jack pine. Muskeg and black spruce-tamarack were used to a lesser extent. In fall jack pine again rose sharply in importance while mixed upland and black spruce-tamarack bog dropped.

Male 304 showed only slight seasonal changes. He used mixed upland almost exclusively in spring and summer. Alder and jack pine ranked second and third, respectively, during the spring months, while jack pine ranked second in summer, with coniferous bog and upland clearing tying for third.



Habitats:

1. Jack pine
2. Mixed upland
3. Black spruce-tamarack bog
4. Muskeg
5. Alder fen
6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

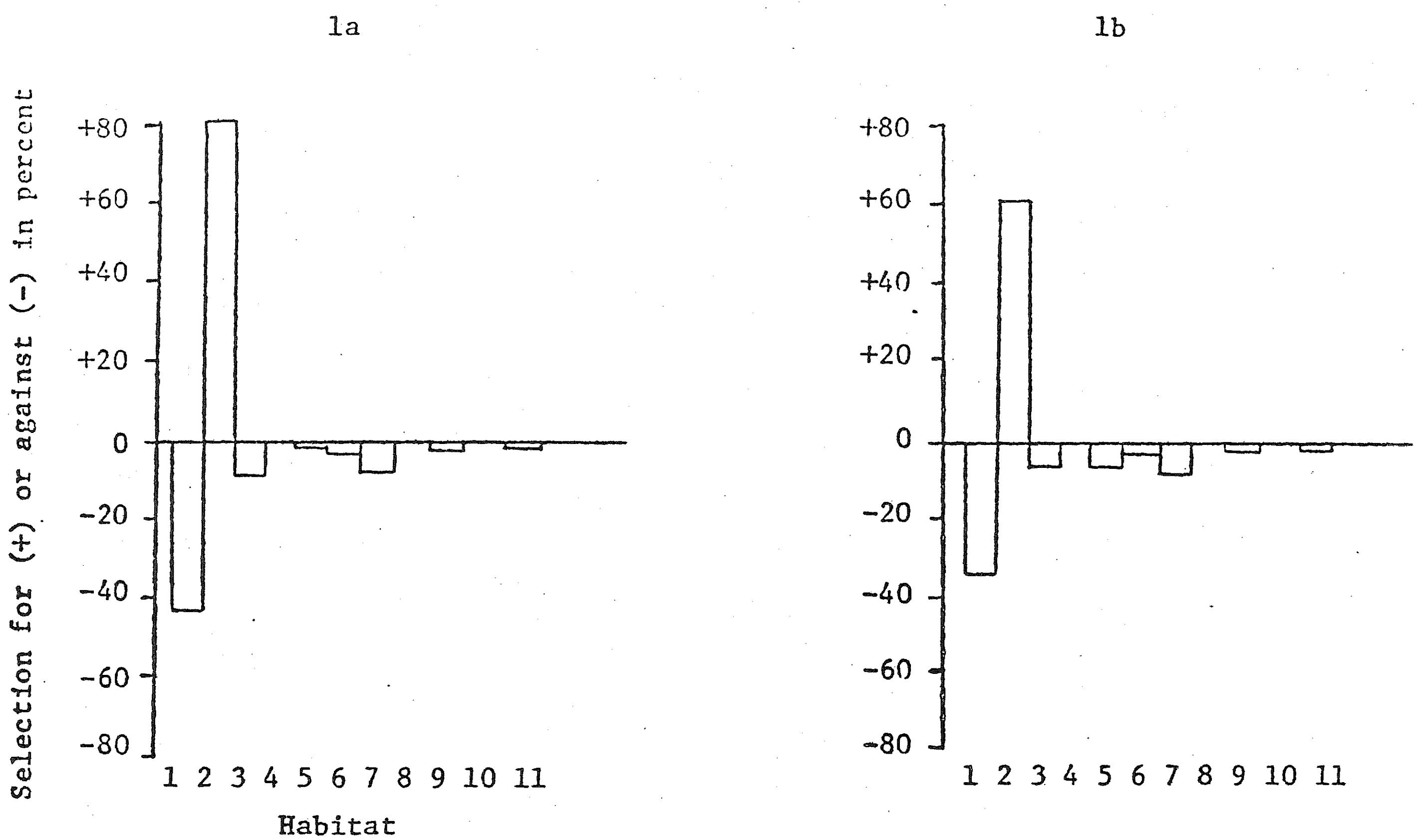
Figure 4. Selection by female ruffed grouse in the Lake Alice study area for (+) and against (-) habitat types, expressed as the difference between the percent of habitat available and the percent of radio-telemetry locations in each type. I. Female 395 - nesting, brooding, and with young (27 May - 7 July 1978), II. Female 567 - after nest predation (22 June - 31 Oct. 1978).

In fall, mixed upland still ranked a strong first but jack pine locations nearly doubled. Black spruce-tamarack bog and upland clearing again showed minor utilization.

Figure 5 reflects the shifts in habitat selection between the spring-summer months and the fall months. Male 305 showed strong selection for only mixed upland in both periods. However, 355 showed a shift from strong to weak selection for mixed upland and strong to weak selection against jack pine. Male 538 showed a shift from strong selection for to weak selection against black spruce-tamarack bog. He also shifted from strong selection against to weak selection for jack pine habitat. All of these patterns of habitat selection were found to be statistically significant.

Incidental sightings of unmarked birds were most common in jack pine (37) and mixed uplands (33), followed by alder (13) and black spruce-tamarack bog (9). Again, however, differences in visibility among these habitat types and differences in the amount of time spent in each type requires that these figures be viewed with some skepticism.

WHITETAIL DEER: Of eight deer captured in March, 1978, only two were suitable for radio-tagging. Males could not be collared due to swelling of the neck during rutting. The two animals, a yearling female and a doe with fawn, are still being monitored in the field. Unfortunately, only the yearling has remained on the study site, and analyses completed to date involve her data exclusively.



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6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

Figure 5. Selection by male ruffed grouse in the Lake Alice study area for (+) and against (-) habitat types, expressed as the difference between the percent of habitat available and the percent of radio-telemetry locations in each type. I. Male 305: a) May-Aug.: b) Sept. - Oct., II. Male 355: a) May-Aug., b) Sept. - Oct. and III. Male 538: a) May-Aug., b) Sept. - Oct., 1978.

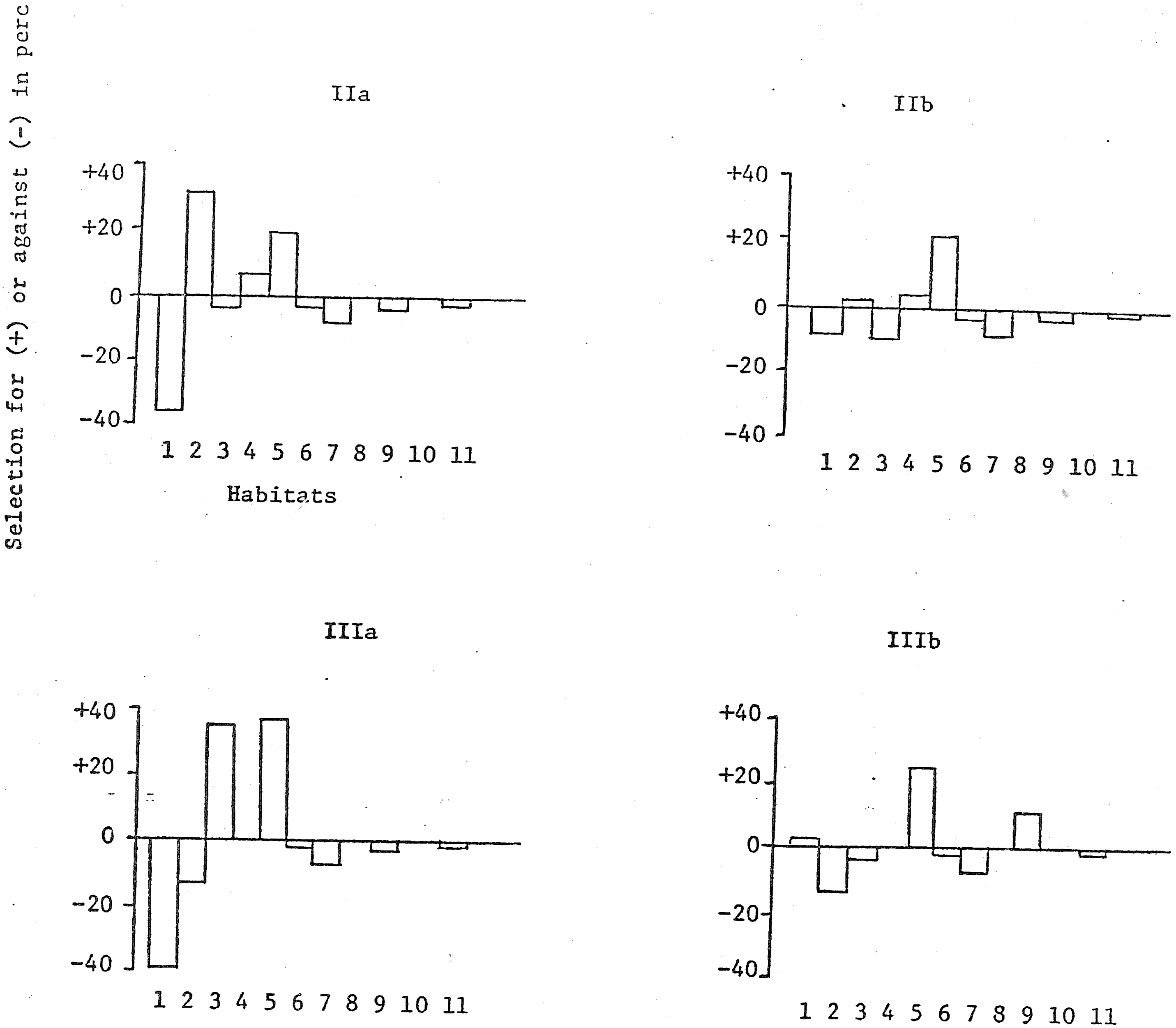


Figure 5. Continued.

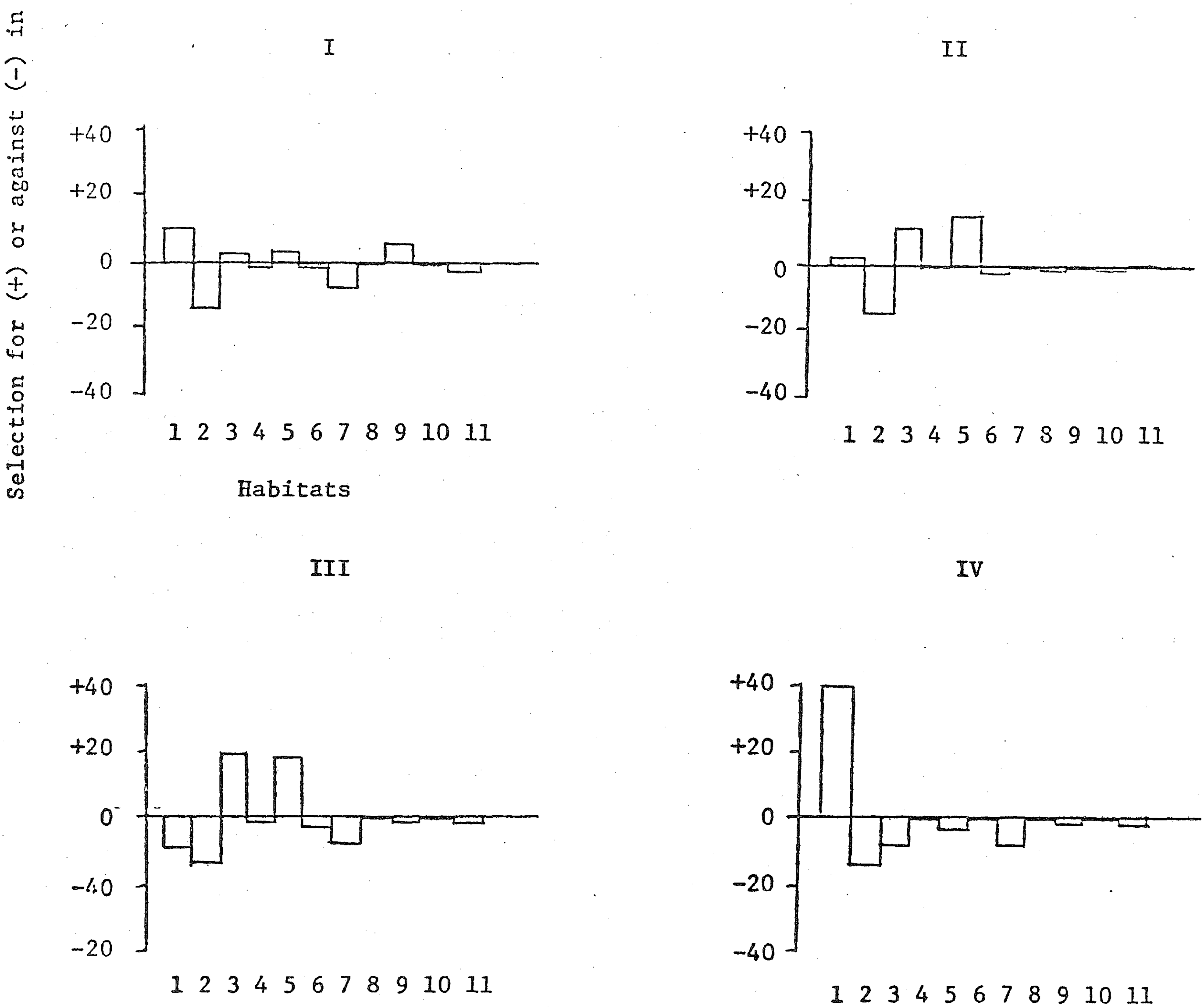
Statistical analysis of day/night habitat use showed no significant difference between the two time periods. Seasonal patterns, however, can be seen clearly in Table 6. Although jack pine was used most often in every month of the year, its percent utilization varied from 39% in August to 91% in October. Alder and black spruce-tamarack bog were generally second and third in importance with both reaching peak values in August and September, but dropping almost to zero in October. In March, as in October, jack pine climbed in importance and alder and conifer bog ebbed to some extent. Sedge fen gained importance only in the month of June. On the other hand, locations were made in upland clearings in all months except June and July. Few locations were made in open bog, muskeg, mixed upland, the road, or open water.

Figure 6 indicates habitat selection shifts for four blocks of time. Jack pine was weakly selected for in March through July, weakly selected against in August through September, and then strongly favored in October. Both alder and conifer bog were selected for, to some extent, from March through September. Patterns of habitat selection were statistically significant in all four periods.

Although analysis of the doe with fawn has been complicated by her utilization of an area almost completely outside our mapped study area, some general comments on her habitat use can safely be made. Unlike the yearling, this deer was located in mixed upland more often than any other type and in jack pine second most often. In addition, no seasonal shifts are apparent as yet.

Table 6. Habitat use by whitetail deer #726 in the Lake Alice study area, expressed as a percent of the total radio-telemetry locations for each specified period, 1978.

Habitat type:	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
				Time period				
Jack pine	73.1	57.8	53.1	45.1	62.5	38.6	48.4	91.4
Mixed upland	0	1.6	0	0	0	3.0	0	0
Black spruce-tamarack	7.7	14.5	12.5	8.8	11.3	32.6	24.2	1.7
Muskeg	0	0	1.6	0	0	0	0	0
Alder fen	7.7	11.3	21.1	21.6	21.3	22.7	25.8	1.7
Scrub fen	0	3.2	3.1	5.9	1.3	0	0	3.4
Sedge fen	0	1.6	2.3	15.6	3.8	0	0	0
Open bog	0	0	0	0	0	0	0	0
Upland Clearing	11.5	9.7	6.3	0	0	3.0	1.6	1.7
Unpaved road	0	0	0	1.5	0	0	0	0
Open water	0	0	0	1.5	0	0	0	0
Total # observations	13	31	32	34	40	33	31	29



Habitats:

1. Jack pine
2. Mixed upland
3. Black spruce-tamarack bog
4. Muskeg
5. Alder fen
6. Scrub fen
7. Sedge fen
8. Open bog
9. Upland clearing
10. Unpaved road
11. Open water

Figure 6. Selection by white tail deer 729 in the Lake Alice study area for (+) and against (-) habitat types, expressed as the difference between the percent of habitat available and thepercent of radio-telemetry locations in each type. I. Mar. - Apr. 1978, II. May-July 1978, III. Aug. - Sept. 1978, and IV. Oct. 1978.

Snow track surveys yielded scanty information on winter deer movements but suggested some utilization of deciduous upland, upland clearing, jack pine and intermediate-sized tamarack stands. The pellet survey showed deciduous upland and jack pine to contain 50% and 45%, respectively, of all the pellet groups found.

Road track surveys (Table 7) indicated that deer most often entered the road from or exited the road into jack pine. Mixed upland was used second most often, but of all types only jack pine was actually selected for.

Totals of incidental sightings of unmarked deer (Appendix B) lend support to the patterns noted above. Sightings were made most often in jack pine and mixed upland types, while no more than two observations were made in any lowland habitats.

Table 7. Road edge habitat use, as evidenced by total sets of deer tracks associated with each habitat type. Numbers represent totals from 19 road track surveys 27 June - 4 October 1978. Percents of road edge adjacent to each habitat were used to evaluate the significance of track totals.

	Total track sets	% of road edge adjacent to each habitat
Jack pine	247.5	42.4
Mixed upland	108.5	28.0
Tamarack bog	15.5	7.5
Mixed lowland (deciduous-coniferous)	7	2.7
Muskeg	4	3.2
Alder fen	11	6.1
Scrub fen	11	1.5
Sedge fen	20.5	6.3
Upland clearing	4	1.7
Logging road	13	.7
Total	443	100.0

DISCUSSION

The results of our work on snowshoe hare suggest that these animals use many habitat types in our area, but that alder and coniferous lowlands are used most intensively. This corresponds well to conclusions reached by Marshall and Miquelle (1978) for years when hares were intermediate in abundance. They state that "While snowshoe hares may be found in all types of forested or bushy areas when they are abundant, during the years of scarcity they are restricted mostly to swamp conifers, swamp thickets, and fen habitats." Similarly, they cite work by Keith (1966) in Alberta where " 'Hares were associated with bog edge thickets of small black spruce and alder and with patches of hazel,'" during periods of low abundance.

Interestingly, the hares in our study area that used mixed upland habitat were found in areas with dense hazel or with thick second-growth aspen and birch. The only hare located predominately in jack pine was usually found in a small shrub-filled depression within the jack pine stand.

In accordance with Marshall's findings at the Cloquet Forest Center, open areas were avoided by all hares. Radio-telemetry, snow track survey and pellet survey results indicate that open lowland as well as open upland habitats are not used. When snows are deep enough to cover low shrubs, much of the scrub fen is also avoided.

Spruce grouse in our study area differed considerably in habitat use patterns from those studied by Haas (1974) and Anderson (1973) in northern Minnesota. In their study area upland conifers were apparently unavailable, and all phases of male and female activity were restricted to various types of lowlands. However, in terms of physiognomy and ground vegetation, sites selected in jack pine by hens in our study showed striking similarities to those used in bog habitats as reported by Haas and Anderson. Apparently, the degree of canopy cover and the types of shrub and herbaceous vegetation available for food are more important then the actual species of trees present in the area.

The importance of conifer bog for the spring and summer activities of adult males has been noted by Anderson (1973) in Minnesota and by Ellison (1971) in Alaska. In Alaska cocks established territories in "moderately dense stands of mixed black spruce and white spruce," the understories of which included Sphagnum masses, blueberry, and lingonberry. Anderson found displaying males in black spruce bogs that had numerous plant species in common with the bogs in our study area.

The literature also supports our finding that a seasonal shift occurs in the relative importance of jack pine and conifer bog. With regard to this, Marshall and Miguelle (1978) cite the work of Stenlund and Magnus in northern Minnesota. These biologists found spruce grouse most often in upland coniferous woods dominated by jack pine. However, "Use of black spruce increased in the summer, almost equaling use of jack pine."

Observations made by Ellison (1973) suggest that the differences in spring movements by our male grouse were related to differences in age. He found that adult males held small territories (1.2-8.5 ha) in late April through May, while "juveniles...did not occupy territories, but wandered widely instead, sometimes covering 2 km in 1 day." If our birds can be assumed to behave similarly, it would appear that we were monitoring one territorial adult male and one nonterritorial juvenile male through the breeding season.

Results of several studies of spruce grouse food habits agree closely with what has been observed in our study area. Marshall and Miquelle (1978) reviewed several of these studies and concluded that conifer needles were the major winter food; leaves and berries of ericaceous plants were among the most important summer foods; and conifer needles gradually became important again through the fall.

The ruffed grouse is not commonly regarded as a member of the peatland fauna; Marshall and Miquelle (1978) did not even mention this species in their review of terrestrial birds of Minnesota peatlands. However, our data showing the importance of alder lowlands to ruffed grouse are not unprecedented, as evidenced by the work of Palmer (1963) in northern Michigan. Palmer found 40 drumming logs, all of which were in lowland cover types. Over 73% of the tall-shrub stems around logs were speckled alder. He emphasized that this size class of vegetation furnished the most important cover for male ruffed grouse.

Of the two whitetail deer that have been monitored during our study, one showed habitat use patterns that were consistent with the literature, and one did not.

A spring study by Pierce (Marshall and Miquelle 1978) in northcentral Minnesota showed deer to be "very individualistic in their habitat preferences." Pierce found animals most often in uplands, while lowland forests were used roughly in proportion to their availability.

Summer work by Kohn (Marshall and Miquelle 1978) revealed that upland habitats were used in proportion to their availability while all lowland habitats were avoided. This is obviously inconsistent with the behavior of our yearling female who showed selection for conifer bog and alder fen throughout the summer months.

Many authors have noted the importance of cedar swamps to deer that are yarding in winter, but have concluded that other types of lowland conifers are of little, if any, importance. Marshall and Miquelle (1978) state that lowland conifer stands do not provide adequate food for over-wintering deer, and thus are used only if there is adjacent upland where food can be obtained. Our area contained none of the favored white cedar, but did provide considerable lowland conifer-upland edge. Radio-telemetry and snow tracking data from winter 1978-1979 should reveal how extensively these areas are used.

The pellet survey taken in spring 1978 suggested that lowland types were generally not important to deer. However, many of the lowland habitats were inundated by melt waters at this time, making it highly improbable that pellets were equally visible in all habitat types. Plans were made to repeat the survey under drier conditions, but heavy rains in summer and fall kept water levels high all year.

The difficult topic of edge effect is of great importance in the study of habitat use by all the species examined here. Although no data have been presented with regard to habitat edge use, we plan to give the question careful study before final analyses are made. Approaches to the study of edge use are made more conplex by the differences in size and mobility of the four species concerned. Undoubtedly the lack of precedence for work in this area will require considerable innovation on our part.

Though data from our study are still being collected, some tenative conclusions may be drawn from analyses completed thus far. It appears that some types of peatlands are used by snowshoe hare, spruce grouse and ruffed grouse, even when upland habitats are available. Alder is important hare habitat and is used for cover by many drumming ruffed grouse males and by some nesting ruffed grouse females. Black spruce-tamarack bogs are used by many hares and by all spruce grouse in at least one season of the year. Some whitetail deer apparently will use alder fen and conifer bog, but there is no general trend among individuals to do so.

REFERENCES

Anderson, L. J. 1973. Habitat use, behavior, territoriality, and movements of the male spruce grouse of northern Minnesota. M. S. Thesis. Univ. of Minn. 119 pp.

Berg, W. C. and R. L. Phillips. 1973. Habitat use by moose in north-western Minnesota with reference to other heavily willowed areas. Paper presented at the International Symposium of Moose Ecology. Quebec City, Quebec. March 25-30. 37 pp.

Bishop, Y. M., S. E. Fienberg, and P. W. Holland, 1975. Discrete Multivariate Analysis: Theory and Practice. The MIT Press, Cambridge. 557 pp.

Ellison, L. N. 1971. Territoriality in Alaskan Spruce Grouse. The Auk 88:652-664.

Ellison, L. N. 1973. Seasonal social organization and movements of spruce grouse. Condor 75:375-385.

Haas, C. H. 1974. Habitat selection, reproduction, and movements in female spruce grouse. Ph.D. Thesis, Univ. of Minn. 124 p.

Leopold, A. Game Management. 1933. Charles Scribner's Sons. New York. 481 pp.

Marshall, W. H. and D. G. Miquelle. 1978. Terrestrial wildlife of Minnesota peatlands, a literature search. Minnesota Department of Natural Resources. St. Paul. 193 pp.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Amer. Midland Nat. 37:223-249.

Palmer, W. L. 1973. Ruffed grouse drumming sites in northern Michigan. J. Wildl. Mgmt. 27:656-663.

Appendix A. Habitat types available in the Lake Alice study area.

	Acres	Percent
Upland conifer (primarily jack pine)	1267.0	51.6
Mixed upland (deciduous & coniferous)	351.5	14.3
Black spruce-tamarack bog	239.0	9.8
Sedge fen	200.5	8.2
Alder fen	148.5	6.0
Upland clearing	95.0	3.9
Scrub fen (primarily bog birch or willow species)	84.0	3.4
Open water	42.0	1.7
Muskeg (5-25% tree cover)	23.5	1.0
Unpaved road	3.5	0.1
Open bog	2.5	.1
Total	2457.6	

Appendix B. Incidental sightings of unmarked animals

	Hares	Deer	Ruffed grouse	Spruce grouse snow cover	Spruce grouse no snow cover
Jack pine	20	23.5	37	116	33
Mixed upland	20.5	19	32.5		
Black spruce-tamarack bog	9.5	.5	8.5		22
Muskeg					
Alder fen	21	.5	13		.5
Scrub fen	3	2			
Sedge fen		1	1.5		
Open bog					
Upland clearing		6.5			
Unpaved road	14	15	2		3.5
Open water					
Total	90	68	94	116	59

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

The methods that have been used to collect data for this project appear to be the most appropriate, and in many cases, the only feasible means of obtaining our specific objectives. However, all categories of data would be improved by increased sample sizes. Especially critical is the need for more deer to be radio-tagged and monitored through all seasons. More male spruce grouse need to be followed through the breeding season, and more female ruffed grouse should be monitored through nesting and brooding stages. Further radio-tracking of male ruffed grouse and of nesting spruce grouse hens would also be of great value.

Additional snow track surveys and pellet surveys would be useful for providing more information on deer habitat use. Pellet surveys should probably be conducted in the driest season of the year, rather than in spring, to prevent inaccurate sampling of low, wet habitat types. Browse surveys for both hare and deer should be done to provide better information on their winter feeding habitats in this area.

SECTION E

PROGRESS REPORT IV

December 15, 1978

Relationship of Amphibians and Reptiles to Peatland Habitats in Minnesota

Principal Investigator: Philip J. Regal

Submitted by: Daryl R. Karns
Project Research Assistant

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1.0 INTRODUCTION

The first field season of the amphibians and reptiles peatland research program was terminated in early October. A great deal of information was obtained in over six months of data collection. Preliminary analysis of that data has occupied the last two months.

It is realized that this progress report is of special importance and, with the other research project reports, will form the basis of DNR's presentation on peatland development to the legislature next year. With that in mind, the goal of this report is to relay the initial results and conclusions from the first field season in a clear, concise form that will allow comparison and integration with other such reports. A tremendous amount of information has been collected. This report is a distillation of that material concentrating on what I consider to be the key topics.

The overall objectives of the amphibians and reptiles peatland research program as stated in the original research proposal have remained essentially the same. Three main questions were posed:

1) What species of amphibians and reptiles are found in the Minnesotan peatlands studied?

2) Peatlands represent a heterogeneous assemblage of habitat types. Which species utilize these various habitats and what is the nature of this utilization?

3) What are the key ecological factors controlling these relationships?

These three questions form the basis for the organization of this report.

Peatlands are a unique ecological theater. Relatively little work in animal ecology has been done in such areas in the United States. This makes the research done by the various projects of special value and importance.

Amphibians and reptiles are an interesting group to examine in such an ecological setting. They are small and ectothermic (cold-blooded). This means they are true residents of an area and track the environment very closely. Amphibians are of particular interest due to their complex life cycles and dependence on water.

2.0 METHODS

2.1. General Information

2.1.1. Study area. The general area under examination was the peatlands of central and southern Koochiching County and western Beltrami County north of Upper Red Lake. This region represents the southern portion of the eastern arm of ancient Lake Agassiz. The most extensive peatlands in Minnesota are found in this part of the state. Work was concentrated in a fifteen mile radius around Big Falls in central Koochiching County. In this area were located the seven trapping sites (discussed below) which were the major source of information. In addition other peatland sites were visited on a regular basis. These include the following: an area approximately 13 miles north of Waskish, Beltrami County; sites along the Pine Island and Lost River Road and the northern edge of the Lake Agassiz Peatlands Natural Area, Koochiching County. Figure 1 shows the location of these trapping sites and observation sites.

2.1.2. Duration of field research program. The program lasted 6-1/2 months: April-mid-October, 1978. This covered the entire period of herpetofaunal activity.

2.1.3. Personnel. Field work was conducted by Daryl R. Karns, research assistant. A volunteer field assistant, Kevin Dickey, was with the project for three months (April-June). Dr. Philip Regal, principal investigator, was the project advisor. The project personnel were housed at the Big Falls Forestry station.

2.2. Collecting Techniques

A variety of methods were employed in the program to collect amphibians and reptiles and gain general information on their natural history in peatland habitats.

2.2.1. Trapping fences (drift fences). These proved to be the key source of information. The trapping fence design used consists of a strip of aluminum flashing (50' x 24") buried 6 inches in the substrate. On each side of the fence one funnel trap is placed and four pitfall (14" deep) traps buried. Any small organism hitting the fence is funneled into one of the traps. These fences provide information on species presence, abundance, and movement. Seven trapping sites were employed, one at an upland site and six at representative peatland habitat sites. It is an effective trap for small mammals and insects as well as amphibians and reptiles.

These fences have long been employed by herpetologists but only until recently have attempts been made to standardize their use as a herpetofaunal census tool (Voght and Hine, 1977; Bury, 1977). These fences are not without problems. There are major maintenance problems in water saturated soils. More importantly, they are a biased sampling technique (see section 3.0). Also all animals were kept and hence eliminated from the population. This places certain qualifications on data interpretation (see section 3.2.3). In spite of these shortcomings the method proved invaluable to the study.

2.2.2. Hand collecting. Traditional search techniques were employed to collect amphibians and reptiles. This is a necessary supplement to trapping, providing information on the animals under natural conditions rather than in a trap. Also for some amphibians and reptiles the trapping fences are ineffective.

2.2.3. Frog call surveys. Periodic surveys were made in the spring to determine which species of frogs and toads were breeding in the area, how long the breeding season lasted, and where breeding sites were located.

2.2.4. Egg and tadpole surveys. Regular surveys of known breeding sites and other areas were conducted to check for the presence of eggs. As the season progressed the course of development of tadpoles at these sites was checked. Simple aquatic sampling techniques were used.

2.3 Water chemistry

Water quality was sampled monthly at a number of sites for most of the season. Amphibian's dependence on water resources and the unique nature of certain types of peatland water prompted this investigation.

2.3.1. Field. pH was taken *in situ* or in bottled samples analyzed in the lab within several hours of collection. Tests showed no appreciable difference between these two procedures. A Radiometer PHM29B portable pH meter with combined electrode was used.

Dissolved oxygen was measured in the field using a Hach OX-2P modified winkler-azide field kit. Unfortunately this proved unsatisfactory in stagnant, highly colored peatland water.

Water color measurement was attempted using a Hach DR-EL/1a colorimeter. Due to unavailability of a centrifuge this proved unsatisfactory.

2.3.2. Lab. Bottled water samples were taken monthly at various sites. These were preserved with nitric acid and stored at 38^{o}F. These samples will be used for ion analysis. This work has not yet been done.

2.4 Experiments

The relationship between peatland water chemistry and amphibian biology, in particular reproduction, was experimentally investigated. Three groups of experiments were done: 1) egg hatching success under various water quality treatments; 2) tadpole survivorship in "bog" vs. upland pool water; 3) adult tolerance to various water quality treatments. Methods employed in the egg and tadpole experiments are presented in section 3.3.4. The adult tolerance experiment has not yet been fully analyzed.

2.5 Habitat Analysis

The habitat analysis information is summarized in the appendix. The data collected come mainly from the trapping fence sites.

2.5.1. Vegetation analysis. Relevés were done at the trapping sites. Methods are described in the appendix.

2.5.2. Micro climate. Each time a trapping fence site was checked the temperature of the air (at chest level in the shade), substrate (in shade and sun), and water (in shade and sun if standing water was present) was taken. These temperatures were taken between 9 AM and 4 PM under a variety of weather conditions at frequent intervals every month. These measurements provide a profile of daytime temperatures at each habitat and allow general comparison.

2.5.3. Climate. The Big Falls Forestry Station collects daily max-min temperatures and precipitation data. These provided an overview of weather in the Big Falls area for the study period. Data were collected by Forestry technician John Lumpio.

2.6 Miscellaneous

In the course of the project a wide variety of information was collected somewhat incidental to the planned research program. These general observations form a valuable background in which to place the results of the planned program. In particular insects and small mammals were collected and preserved. The small mammals have been turned over to Gerda Nordquist of the peatlands small mammal program. Information on large mammals and birds was shared with members of the other peatland programs and vice versa.

3.0. RESULTS

There are certain qualifications that must be stressed in presenting the results of the first field season: 1) For obvious reasons of practicality a very small portion of the Minnesotan peatlands has been examined. These results are valid only for the study area described. 2) The techniques used are biased. The trapping fences are effective with small ground litter amphibians and reptiles.

Larger species and semiarboreal species are not effectively sampled. Hence excellent information is available for certain species and virtually none for others.

3.1. The Peatlands Herpetofauna

Over the course of the field season approximately 1300 specimens were collected. Over 90% of these came from the trapping fence sites. This collection is now deposited at the Bell Museum of Natural History at the University of Minnesota. It is unique in that it covers an entire herpetofaunal activity season from boreal peatland habitats. To my knowledge no comparable collection exists in the United States. When amphibians and reptiles are collected the entire animal is kept, hence such a collection contains a great deal of information (e.g. seasonal population changes, reproductive cycles, diet).

What species are found in the peatland habitats studied? Table 1 presents a species list for the area. Five frogs, one toad, two salamanders, two snakes, and two turtles were found. No lizards were found. Note the qualifications listed. The subspecific taxonomic problems mentioned will be dealt with in the final report. Table 2 is a species list from Itasca State Park. It is of interest since this area is a geographically close typical northern Minnesota non-peatland area. It is in a mixed hardwood-conifer zone dotted with lakes. Some small lake basin peat areas are found here.

Note the greater species diversity at Itasca (eight frogs, one toad, four salamanders, five snakes, one lizard, and two turtles). Implications of these lists are discussed in section 4.1.2.

3.2. Habitat Utilization

A species list by itself does not offer insight into how peatland habitats are utilized by amphibians and reptiles. The peatlands are a heterogeneous assemblage of habitat types. How do these animals interact with this complex environment? A main objective of this study was to determine which species are associated with these various habitat types. Using the collecting techniques described in section 2.2. six peatland habitats and one upland site were intensively monitored. These seven sites are the main source of the following information. For comparative purposes the appendix contains background information on these habitats and should be consulted. Areas surveyed other than those sites are discussed briefly at the end of this section.

Table 3 shows the total number of individuals of each species caught in the various habitat types. This includes trapping fence and hand collecting data. Table 4 utilizes trapping fence data only and shows the number of individuals caught per species per day in each habitat type. These two tables show the same patterns from slightly different perspectives. They provide an overview of which species are associated with the various habitats. The following section presents in outline form what I consider to be the important points of these tables. For each species I have indicated: 1) if the trapping fence is effective with this species; 2) general habits of the species; 3) where it was found; 4) comments. Species are listed in the general order of importance. For each habitat a brief summary statement is provided. I will follow the habitat/vegetation abbreviations used by Fox et al. (1977).

3.2.1. Species accounts:

Rana sylvatica (Wood Frog)--Trapping fence effective; diurnal ground litter species; found in all habitats. Comments: R. sylvatica and Bufo a. americanus (American Toad) are the most conspicuous and dominant amphibians of the peatland habitats studied. These two species account for 46.0% and 41.1% respectively of the total number of individuals caught. Compared with B. a. americanus R. sylvatica exhibited a preference for wetter sites.

Note the strong dominance of R. sylvatica in the very wet SCT, and FO/ST. The situation is reversed in the relatively dry SCS. Both were abundant in the upland and SCSRb. Both were relatively rare in the BO and SCC.

Bufo a. americanus (American Toad)--Trapping fence effective; nocturnal ground litter species; found in all habitats. Comments: see above.

Pseudacris triseriata (Chorus Frog): Trapping fence effective; ground litter species; marked preference for upland habitat, occasionally found in SCC, rare or absent in other habitats. Comments: P. triseriata was notable for its preference for rich minerotrophic sites, both for breeding and later in the season. It was notably rare or absent in sites dominated by sphagnum.

Ambystoma laterale (Blue-spotted Salamander)--Trapping fence effective; secretive, largely subterranean species; caught in all habitats but SCT, marked preference for upland. Comments: This is the only terrestrial salamander found in the peatland habitats studied. It was not caught in large numbers relative to the above three species. This is undoubtedly due in part to its secretive underground life style. During the time of spring breeding and fall overwintering movements it is more conspicuous.

Rana pipiens (Northern Leopard Frog)--Trapping fence effective; diurnal ground litter species, often associated with larger ponds, lakes; rare or absent in habitats sampled. Comments: _R. pipiens_ was notably rare or absent in peatland habitats in general, especially in sites dominated by sphagnum. It was noted to be locally abundant in certain areas (upland pools, ditches, very wet fen habitat near upland), but not the dominant species it is in adjacent non-peatland areas (e.g. Itasca).

Hyla c. crucifer (Northern Spring Peeper)--Trapping fence not effective; semiarboreal species; probably found in all peatland habitats. Comments: Low capture rates due to its semiarboreal secretive habits make generalization difficult. It is, however, a common peatland tree frog. During the breeding season this was a conspicuous species, calling from a wide variety of habitat types.

Hyla versicolor (Gray Tree Frog)--Trapping fence not effective; semiarboreal species; only five individuals caught (at an upland breeding site). Comments: Low capture rates due to its semiarboreal secretive habits make generalization difficult. During the breeding season breeding choruses were much more clumped in distribution than _H. c. crucifer_. _H. versicolor_ seemed more restricted to upland pools, FO and ST adjacent to uplands which offered the shrubby calling sites this species prefers.

Thamnophis s. sirtalis (Eastern Garter Snake)--Trapping fence somewhat effective (funnel traps effective for all sizes, pitfall traps effective for smaller snakes); ground litter species; caught in low numbers at upland, BO, and SCS. Comments: _T. s. sirtalis_ was the most conspicuous reptile of the peatlands sampled. It was mostoften seen or collected at drier sites; one individual, however, was taken in very wet BO. This is a generalist species noted for its wide range of habitats.

Storeria o. occipitomaculata (Red-bellied Snake)--Trapping fence effective for most sizes; ground litter species; caught only at the upland site. Comments: this snake is smaller than T. s. sirtalis and the trapping fences should be effective for all but the largest adults. However, only eight individuals were caught, all from the upland. This snake has been reported from sphagnum bogs (Conant, 1975; Pietz, personal communication [noted in a lake basin bog at Itasca State Park]). This snake is also known for its spotty distribution.

Chrysemys picta belli (Western Painted Turtle)--Traps ineffective except for very small individuals; aquatic species preferring shallow water of large ditches, ponds, etc.; found only at upland sites. Comments: Only three individuals of this species were seen, two at upland pools and one at a roadside ditch adjacent to a small fen. Probably abundant in ditches, permanent ponds, and streams of the general area.

Note: The following two species were not actually caught or seen in the study area. Available evidence (Conant, 1975; Breckenridge, 1970; Koochiching County residents, personal communication) indicates their presence in the study area.

Necturus m. maculosus (Mud puppy)--Trapping fence ineffective; completely aquatic species, nocturnal. Comments: This species prefers lakes, ponds, rivers and streams and other permanent bodies of water. It is probably found in the stream and river systems which drain the peatlands studied. Special techniques are required for collecting.

Chelydra s. serpentina (Common Snapping Turtle)--Trapping fence ineffective; largely aquatic species. Comments: see above.

3.2.2. Habitat accounts:

Upland: Both in terms of the number of species recorded and number of individuals caught the upland habitat was the most diverse and productive. Ten species were caught or seen in upland sites. More individuals were caught in upland sites, both in terms of absolute numbers and numbers caught per day. R. sylvatica, B. a. americanus, and P. triseriata were the dominant species. This trapping site was immediately adjacent to a small fen which was an active breeding area. This undoubtedly was a factor in the site's productivity.

Open Bog (BO) and Swamp Conifer Spruce-Raised Bog (SCSRb): Only two species were encountered in abundance, R. sylvatica and B. a. americanus. About twice as many individuals of both species were caught in the more closed habitat of the SCSRb than in the virtually treeless BO. These trapping sites were only about 200 yards apart (see Relevés 2 & 3).

Swamp Conifer Tamarack (SCT): SCT was an extremely wet site. It was dominated by one species, R. sylvatica.

Swamp Conifer Spruce (SCS): SCS was a relatively dry habitat, with little standing surface water. B. a. americanus was the dominant species.

Swamp Conifer-Cedar/Spruce (SCC): SCC was the least productive of the habitats examined both in terms of total number caught and number caught per day. This was a dense shady cold habitat (see appendix). However SCSRb was similar in this respect, yet produced almost three times as many specimens. The reason for this may involve the fact that the SCC site was located in an extensive area of dense shady cover whereas SCSRb was a relatively small such patch grading into more open habitat on all sides.

Open Fen/Swamp Thicket (FO/ST): FO and ST formed a mosaic at this very wet site. R. sylvatica was the dominant species. This was the only site at which R. pipiens was regularly caught in the trapping fences.

Other Sites: Peatland sites surveyed along Pine Island Road, Lost River Road, and the northern edge of the Lake Agassiz Natural Peatlands contained extensive areas of BO, SCSRb, SCS, SCT, FO and ST. Observations and collecting in these habitats showed the same species and habitat utilization patterns found in the Big Falls area.

The immense patterned peatlands north of Upper Red Lake present a different habitat structure than the other sites examined. We surveyed at several sites north of Waskish off Hwy. 72. The same general group of species was found. The exact effect of the fen/Black Spruce island topography on herpetofaunal habitat utilization is not known. _R. sylvatica_ and _B. a. americanus_ again seemed to be the dominant species.

3.2.3. _Seasonal movements_. The above information provides a valuable overview of the herpetofauna of the peatlands studied. Tables 3 and 4 do however clump information from an entire season for a given species and habitat type. Much information concerning the details of habitat utilization is hidden in such an overview. Each species collected was analyzed by sex, size, reproductive condition, date of capture and habitat. From this information patterns of movement emerge.

This analysis deals only with trapping fence data. This data is subject to an important qualification: All animals caught in the fences were kept hence this technique removes animals from an area. Many amphibians and reptiles have home ranges and remain in a fairly well defined area after postbreeding dispersal (Porter, 1972; Bellis, 1965). Trapping fences would tend to eliminate such local residents. Sustained high numbers of captures indicate a high level of movement in that area. A sustained low level of captures could indicate dispersal from that area or an elimination of local residents or some combination of these two.

I have concentrated on those species and habitats for which the greatest information is available. For purposes of this section I have lumped the adjacent sphagnum bog sites: BO and SCSRb. Figures 2-5 present changes in the number and size of individuals in the given habitats. The 6-1/2 month activity season is broken into two periods: April-June and July-mid-October. This effectively separates early season breeding activity from post-breeding dispersal and feeding activities.

For R. Sylvatica I have compared three habitats, upland, SCT, and BO/SCSRb (Figures 2-4). The upland fence was located near an active breeding site. Virtually all males and females caught in the early part of the season were in reproductive condition. This period is clearly dominated by breeding adults. SCT shows much the same pattern. However activity begins later. No frogs were caught at the SCT site in late April, while the nearby upland site was intensely active.

The BO/SCSRb site reveals a striking difference: 1) Frogs were not even caught at these bog sites until May 15, almost a month after upland activity began. 2) These early season captures at BO/SCSRb are a different class of individuals. They are smaller and all nonreproductive. Hence there is a dramatic difference in the time bog activity begins and in the age-size class found during this period.

For R. sylvatica in the July-mid-October period the upland site shows a large drop-off in the number of individuals caught relative to the April-June period (10 vs. 82). Also a new age-size class appears as metamorphosed young move onto the land. It would seem that the upland breeding site area is largely abandoned as frogs disperse in the latter part of the season. A contributing factor may be the increasing dryness of this site as the season progresses.

As noted above other interpretations of low capture number data are possible since all animals caught were kept. The interpretation offered is considered the most likely based on other studies (Bellis, 1957, 1959, 1965) and field observations at the time.

The SCT site does not show this dispersal pattern. Adult frogs in numbers comparable to that of the early season remain. A new age-size class appears as the young frogs arrive. The all season wetness of this site is probably a contributing factor.

The BO/SCSRb sites witnessed a true invasion. Beginning in July large numbers of adult age-size class frogs appear and remain for the rest of the season. I interpret this invasion as a post-breeding season dispersal away from the adjacent highland. In the later part of the season many of the larger females had developing ovaries.

B. a. americanus shows much the same pattern in the upland and BO/SCSRb sites. Figure 5 shows this pattern for the bog sites. Again small and/or nonreproductive toads are found in the early part of the season. As with R. sylvatica no animals were caught until May 15. Later in the season an invasion of larger toads occurred. Again some of these are of reproductive size with developing eggs for the following season's breeding.

P. triseriata was largely an upland species. It was abundant during the spring breeding, tapered off during the summer and then reappeared in some numbers in the fall at the upland site. This can be interpreted as corresponding to the breeding period, post-breeding dispersal, and fall movement back to the breeding site to overwinter in anticipation of the following season's breeding.

A. laterale was an uncommon species. It was caught in low numbers throughout the season at the upland site. Of interest is the fact that four salamanders were caught at the BO/SCSRb sites in September heading north toward the upland. These were the only A. laterale caught at these sites all season. Salamanders are well known for their fall seasonal migration to overwintering sites near breeding locales (Porter, 1972; Conant, 1975).

These September captures are suggestive of such a movement.

3.3. Factors Affecting Habitat Utilization: Water Quality and Amphibian Breeding Ecology

Amphibians require water in which to breed and for larval development. Figure 6 shows the general outlines of breeding periods for the predominant amphibians of peatland habitats. They fall into distinct categories in terms of reproductive behavior: explosive breeders which engage in intense fairly synchronized breeding activity for a short period (*R. sylvatica*, *B. a. americanus*, and *A. laterale*) and prolonged breeders which spread breeding activities over a longer period of time (*P. triseriata*, *H. c. crucifer*, and *H. versicolor*). The relationship between amphibian reproduction and the water resources available to them in peatland habitats was an area of major investigation.

3.3.1. *Water chemistry*. Water chemistry parameters were monitored at a number of sites from May-August. This is the seasonal period of importance when eggs are laid, hatch and the larvae develop. The very early part of the breeding season in late April was not monitored (see section 2.3 for methods).

Table 5 shows the pH measurements taken at various sites over the season. These measurements were taken only from standing water since that is what breeding amphibians would deal with. Low pH is an excellent indicator of weakly minerotrophic or ombrotrophic water, hence ion-poor water. Ion analysis (not yet completed) is required for more precise categorization. Also pH is a rather difficult parameter to measure. It varies slightly from spot to spot at a given site at the same time, not to mention diurnal, seasonal and weather induced changes (Heinselman, 1970). Table 5 shows, however, that in spite of this natural variability, it is a relatively stable environmental parameter at the sites examined.

A broad spectrum of water quality is also revealed in Table 5. At the acidic end are sphagnum sites associated with probable raised bog complexes at BO and SCSRb and the bog drain at Porter Ridge Road. pH values are <5.0, indicating ombrotrophic--weakly minerotrophic waters. The open sedge fens around the Big Falls area fall into the 5-6 pH value range. This indicates weakly minerotrophic to minerotrophic waters. The remainder of the sites, which include upland, peatland ditches, SCT and open fen north of Red Lake, are generally >6.0, indicating rich minerotrophic sites.

In addition to areas of relatively stable pH there were transition zones in which pH varied dramatically over short distances. Heinselman (1963, 1970) and others (references in Boelter and Verry, 1976), have made similar observations and noted the obvious interrelated influences of vegetation, hydrology and topography. For example, at Porter Ridge Road the road bisects an open sedge fen bordering an upland ridge; this fen graded off to the southeast into a bog drain with obvious changes in vegetation. The pH change from the fen/upland interface into the drain at ~ 100 yard intervals was as follows: 6.1, 5.6, 5.1, 5.0, 4.6, 4.1. Near Waskish another narrow transition zone was noted between the edge of a Black Spruce teardrop-shaped island and the adjacent open fen. The pH went from 4.1 at the edge of the island to 6.1 in the fen within 500 feet (these measurements taken from standing water). Many similar examples could be given.

The conclusion from such findings is that peatland amphibians deal with a very heterogeneous environment in terms of water quality.

3.3.2. <u>Breeding site preferences</u>. Twenty breeding sites were investigated. Often more than one species bred at a particular site, indicating much overlap in breeding site preference. For the six amphibian species examined the following generalities can be made:

<u>pH</u>. A range of 5.7 - 9.08 was noted at breeding sites. An important observation was that, with the exception of several isolated calling <u>H</u>. <u>c</u>.

crucifer and B. a. americanus, breeding choruses and egg masses were never associated with acidic ombrotrophic-weakly minerotrophic sites. This was dramatically apparent at narrow transition zones between water quality types. Breeding sites were always located on the minertrophic side of such zones. Caution is necessary in interpretation of such observations since other factors (e.g. temperature, vegetation) must be considered.

Water depth. Depth varied from 2-3 inches in shallow ponds and fens to five feet in larger ditches.

Configuration. Breeding sites came in all shapes and sizes ranging from small depressions to large shallow ponds and narrow deep ditches. No real generalization is possible other than to note the opportunistic nature of amphibians in breeding site selection.

Vegetation. No real preferences were noted. What seemed important was simply the presence of some suitable floating substrate for egg attachment. Carex spp., Typha spp. and Calamagrostis were plants often noted.

Egg mass location. Eggs are dependent on temperature for rate of development. Egg masses often were located at relatively shallow sites providing good sun exposure, hence a favorable local thermal environment for the egg mass.

3.3.3. Tadpole survey. After the breeding season tadpole surveys were conducted monthly at known breeding sites and other locales. This was done to check on the quality of breeding sites in terms of successful egg hatching and subsequent tadpole development. Tadpoles were found under a rather remarkable variety of conditions.

Also of interest was the relationship between tadpoles and water quality, in particular pH. Tadpoles were never found in water of pH < 5.0 and usually < 5.3. Hydrologic transition zones were intensively searched in this regard.

The Porter Ridge Road fen/bog drain zone as described in section 3.3.1. is an excellent example. There is no physical barrier to tadpole movement in this water basin, yet tadpoles were never found toward the acidic, ombrotrophic side of the transition zone where pH values dropped below 5.3. A number of similar sites with abundant surface water showing classic ombrotrophic-weakly minerotrophic conditions were searched for tadpoles. They were never found. This suggests an active avoidance of such areas due to water quality or the nature of other resources associated with these environments.

One breeding and tadpole site deserves special mention. *R. sylvatica* was found to breed in open patterned fen habitat north of Upper Red Lake (the locality was ~13 miles north and ~ 1-1/2 miles west of Hwy. 72). Egg masses and subsequently tadpoles were found in the hollows between the vegetation ridges. These ridges and hollows create the transverse patterning seen from the air. Only *R. sylvatica* was found. *H. c. crucifer*, *H. versicolor*, and *P. triseriata* were associated with the large ditch network in the region. As the season progressed many of these hollows became dry on the surface with no visible standing water. Yet large tadpoles could be found under this vegetation mat, feeding and growing in this very shallow compressed aquatic microhabitat.

3.3.4. Egg and tadpole water quality experiments. In the original research proposal water quality in peatland habitats was noted as a potentially powerful agent affecting amphibian biology. The field observations noted above tend to confirm this. It was decided to experimentally investigate the tolerance of eggs and tadpoles with a series of different water quality treatments.

Acidity is immediately suspect as a key factor in the observed "avoidance" by breeding amphibians and tadpoles of acidic ombrotrophic-weakly minerotrophic water. Acid toxicity is a documented phenomena for certain frogs, toads, salamanders, fish, and various invertebrates (Allee, et al. 1950; Pough, 1976; Gosner and Black, 1957; Gorham, 1976; and Dunson, 1973, 1977). It must be stressed, however, that "bog water" is a complex chemical solution and other factors may be involved (see section 5.2).

Methods. Five water treatments were used: Three circumneutral treatments--1) upland pool water from a known breeding site; 2) untreated mineral well water; 3) neutralized acidic bog drain water buffered with NaOH to a pH of $\sim$7.0. Two acidic treatments--1) bog drain water; 2) acidified mineral well water treated with H_2SO_4 to a pH of $\sim$4.1. Two separate groups of eggs were tested with each treatment for each species. Three species were used: *R. sylvatica*, *H. c. crucifer*, and *B. a. americanus*. Freshly laid eggs were obtained in the lab from *B. a. americanus* and *H. c. crucifer*. Developing egg masses were obtained from the field for *R. sylvatica*. An attempt was made to put approximately equal numbers of eggs in each treatment for a given species. The experiments were run until it was readily apparent that all hatching that was going to occur had occurred. The number of tadpoles and unhatched eggs were counted at regular intervals. The pH of the various treatments was monitored and the water changed at regular intervals throughout the experiment. pH did vary in the course of the experiments for a variety of reasons but the important treatment differences were consistent.

The tadpole experiments consisted simply of placing groups of tadpoles in two water treatments: upland pool and bog drain water. The jars were inspected each day. pH was monitored and water changed at regular intervals. The experiment was run until an obvious effect had occurred. The number of surviving tadpoles in each treatment was then counted. Two species were used: *R. sylvatica* and *B. a. americanus*.

Results: Egg hatching experiments. Tables 6 and 7 present the results of the *B. a. americanus* and *H. c. crucifer* experiments. The *R. sylvatica* experiment was not analyzed. It was difficult to interpret the results due to the fact that rather advanced egg masses from the field were used. The *R. sylvatica* experiment will be duplicated with freshly laid egg masses next season.

The results of the *B. a. americanus* and *H. c. crucifer* experiments with freshly laid eggs were clearcut. There was a high level of successful hatching with the three circumneutral water treatments. The two acidic water treatments were essentially lethal. These differences are highly significant statistically (see Tables 6 and 7). This correlates well with the field observations noted. It also strongly suggests that acidity is a major factor. Note that normal tap water is a very favorable hatching medium. By adding one factor (hydrogen ions from H_2SO_4) which lowers pH, tap water becomes a lethal hatching medium. The neutralized bog drain treatment shows the opposite effect resulting in successful hatching. It must be stressed that the NaOH used in this treatment could be interacting with other factors than just acidity.

Results: tadpole experiments. Table 8 shows the same general result: the acidic environment is highly deleterious. Again results are highly statistically significant (see Table 8). With only the two treatments, however, the results are somewhat more ambiguous. One important factor with tadpoles is food. I attempted to mimic a natural feeding environment by using the aquatic vegetation that would normally be found in these two environments. Bog vegetation is notoriously low in nutrients. It is conceivable that the tadpoles could starve to death on such a diet. However, the very rapid demise of the *B. a. americanus* tadpoles argues for a water treatment effect. A few

R. sylvatica lasted for a considerable period. Most, however, died within two weeks.

4.0. DISCUSSION

Before making any generalizations concerning the data presented, it is necessary to reemphasize several points: 1) These are preliminary conclusions based on one field season and the available literature. 2) The following discussion is based largely on information from the study area described. This represents a small portion of the Minnesotan peatlands. 3) The techniques used have certain unavoidable biases (see section 3.0.). Hence this discussion is necessarily based on those species for which data are most complete and reliable from a relatively small area in one peatlands region.

4.1. Nature of the Peatlands Herpetofauna

In considering the data collected and other available information three main generalizations concerning the boreal peatlands herpetofauna studied emerge:

4.1.1. The dominance of amphibians. Amphibians are clearly the dominant element of the peatlands herpetofauna. This is true both in number of species and abundance. This is not surprising when one considers basic amphibian biology, particularly this group's dependence on water.

4.1.2. Low relative species diversity; the restrictive nature of peatland habitats. The peatlands do not have a diverse herpetofauna. Amphibians and reptiles are, however, abundant in the areas studied; there are many individuals of relatively few species. In part this is to be expected. Amphibians and reptiles are ectotherms suited to warmer, particularly tropical, environments where they are abundant and rich in species. They are not "good" northern colonizers. For example, if one looks at the number of species of frogs and toads in areas progressively further north the following is found: Mexico (161);

Washington State (11); Minnesota (14); Alaska (3). There is a striking latitudinal dropoff in the number of species. The peatlands, however, seem to be species poor even for a northern temperate herpetofauna. Comparison of the species list for nearby Itasca State Park (Table 2) and the peatlands list (Table 1) shows major differences; in particular there are more species of terrestrial reptiles found at Itasca. Itasca is a typical northern temperate mixed hardwood-conifer lake district. The important point is that there seems to be something restrictive about the peatlands in terms of amphibian and reptile colonization and hence distribution.

It is interesting to consider the peatlands studied in terms of what is not present. The distributions of a number of species seem to skirt the edge of the extensive northern Minnesotan peatlands (distribution information from Conant, 1975; Smith, 1978; and Breckenridge, 1970). For example, *Eumeces s. septentrionalis* (Northern Prairie Skink) is found to the south and northwest of the study area in Minnesota and also in southern Manitoba. It is a burrowing lizard usually found in areas of soft sand or soils often in gravelly or sandy glacial deposits (Conant, 1975). Such deposits exist in the study area but are widely scattered with extensive stretches of peatland between them. The wetness of the peatlands may serve as an impassable barrier to these sandy "islands" hence barring extension of this northern species into the area.

Ambystoma t. tigrinum (Eastern Tiger Salamander) is also found to the northwest and extends into Canada. It can be found 60 miles south of Big Falls but apparently does not penetrate into the peatlands study area. This salamander usually breeds in large permanent ponds or lakes where its slow-growing carnivorous larvae often overwinter. The shallow pools and ponds of the peatlands freeze solid thus precluding such a strategy. The lack of permanent ponds and lakes may be an important limiting factor in its distribution.

Rana septentrionalis (Mink Frog) is a true frog of the north. It ranges far into northern Quebec. It is a very abundant frog in the Lake Itasca area to the south. This species seems to skip over the study area. It is found near the borders of ponds and lakes or the cold waters near the mouth of streams. It is usually associated with lily pads. Again the lack or scarcity of desirable ponds and lakes may be a key factor.

Other such examples could be given. I would suggest that for many species the peatlands studied may be either too wet or not wet enough. By this I mean that the peatlands, with their generally water-saturated soils may prohibit species requiring drier conditions. This is probably an important factor in the relatively low number of terrestrial reptiles found. On the other hand the water is not very localized. The area can be thought of as a vast shallow subsurface river in many respects. Amphibian species, in particular, requiring deeper, permanent bodies of water may also be prohibited from successfully colonizing the area.

These of course are suggestions. A great deal more work would be needed to pin down the factors involved in the distributional patterns noted. However, the fact of low species diversity in the peatlands studied relative to adjacent northern habitats remains.

4.1.3. Species composition. No peatland specialists were found; by this I mean no species were found which were restricted to peatland habitats. The herpetofauna is composed largely of generalist species, noted for the wide range of habitats in which they are found.

This is in contrast to other bog areas that have been studied. For example, the bogs of the New Jersey Pine Barrens are noteworthy for Hyla andersoni (Pine Barrens Tree frog). This is an endangered species which breeds preferentially in sphagnum pools of the area. Also from the east coast is the more widely spread Rana virgatipes (Carpenter Frog, also called the "sphagnum frog") noted for its close association with peat bog habitats

(Conant, 1975; Gosner and Black, 1957; Smith, 1978; and Noble, 1923).

We found no localized species of this nature for which the peatlands could be designated as critical habitat. In the area studied there was nothing found which could be considered rare or endangered. This does not eliminate the possibility. We simply found no evidence of such a species in the relatively small area examined. The examples cited above set a precedent for the existence of such a peatlands specialist.

4.2. Factors Controlling Peatland Habitat Utilization

The species which are found in the peatlands studied are faced with a heterogeneous assemblage of habitat types, each with its own set of resources. There are often abrupt transitions (e.g. Black Spruce Island into open fen or upland ridge into raised bog); also there are areas of extensive gradation of types where characterization is difficult. Important patterns of differential habitat usage for peatland species were found. These are summarized in sections 3.2.1. and 3.2.2. by species and by habitat type.

For example *P. triseriata* was found to be associated mainly with wooded upland sites throughout the activity season. It seemed to avoid water-saturated peatland habitats of most types (Tables 3 and 4). *R. sylvatica* and *B. a. americanus* on the other hand were ubiquitous and abundant "weed" species. They were found in all habitat types at some time. However, there were major seasonal differences in the number and class of individuals found in various habitats at different times (see section 3.2.3.). From the analysis of these patterns several key factors emerge:

4.2.1. Temperature. Climate is the major external controlling agent of habitat utilization. For ectotherms such as amphibians and reptiles temperature is probably the single key factor. For these animals temperature can be thought of as a habitat "gate keeper". A habitat does not become available until average microhabitat temperature values reach a species' thermal activity range. This has important consequences in the peatlands, particularly in the spring. Certain habitats (e.g. SCSRb, SCC, see appendix, Table 2A) remain colder longer and hence unavailable. A sequence of activity occurs as habitats become available. For example, the upland site became active first, followed by SCT and a month later by SCSRb and BO.

When breeding was occurring in various upland and SCT sites studied there was still snow and ice present in nearby SCS areas.

4.2.2. Precipitation. Rainfall is not the key factor in peatland habitats that it is in drier areas. Rainfall is correlated with local movements, however. It was found in this study and many others (e.g. Savage, 1961; Voght & Hine, 1977) that amphibians, in particular, are moving and consequently more are caught during rainy or extremely humid periods.

4.2.3. Resource availability. The life cycle of any organism has crucial links. If the proper resources are not available at the proper time the organism may perish or fail to pass on its genes. It is valuable to view the peatlands in terms of crucial resource availability. Three key phases of the amphibian life cycle will be discussed in this regard:

Breeding. Amphibian reproduction requires standing pools of water which last for a reasonable period of time. Obviously there is a great deal of water in peatland habitats; the question is one of quantity and quality. As noted before, many peatland habitats are like vast, shallow subsurface rivers. They are wet, but satisfactory local accumulations of water may be scarce or absent. A raised bog is a good example of a water-saturated habitat where there is often little or no surface water present.

Water quality is also important. The egg hatching and tadpole experiments (see section 3.3.4.) clearly demonstrate the toxic properties of acidic, ombrotrophic-weakly minerotrophic peatland water for three species. These experiments did not isolate with certainty the causal factor(s) (see section 5.0); however, the ecological significance remains.

Thus in terms of breeding we have a rather paradoxical situation: wetland habitats in which much of the water may be unusable, due either to the quality of the water or the manner in which it is distributed in the environment. "Good" breeding sites become a valuable restricted resource. This will obviously influence habitat utilization.

Water balance. Amphibians are not "well designed" terrestrial animals. They are constantly losing water through evaporation even when humidity is high (Porter, 1972). Water saturated peatland habitats are clearly a resource for such organisms. For metamorphosed individuals all that is important is body contact with a wet substrate; hence the limitations on water availability noted above do not apply.

Peatland habitats, except perhaps in times of extreme drought, can perhaps be considered as osmoregulatory refuges in which favorable water balance conditions can always be found. This may be an important factor in the disappearance of animals from the drier uplands (section 3.2.3.).

Overwintering. Both amphibians and reptiles in this area spend approximately half of the year dormant, burrowed in at overwintering sites. Without the proper sites and/or under severe winter conditions mortality can be high. Clearly overwintering sites are a key resource.

The available evidence suggests that water-saturated habitats may offer severe constraints as to where overwintering can successfully occur. Amphibians differ in their ability to tolerate sustained immersion in water (Schmidt, 1965; Karns, this study, in preparation). Recent studies (Hodge, 1976; Ewert, 1969) indicate that overwintering survival is apparently correlated with the dryness of the site for some species. Mortality is high in moist sites for these species. Hence suitable overwintering sites may be a very restricted resource in peatland areas. Further investigation of this problem is planned.

5.0. RECOMMENDATIONS

5.1. Impact of Development on Peatlands Herpetofauna

It is impossible to say anything specific about the effects of major peatland development on the peatlands herpetofauna at this time. A few general points can be made.

Amphibians and reptiles are an important element of the peatlands community. These groups may not be rich in species, but they are abundant. Their importance in the food chains and general maintenance of wetland ecosystems has been well documented (Neill, 1974; Porter, 1972). Any disturbance affecting them would certainly have ramifications for many other species. In this respect their lack of importance in human economic terms is misleading.

If major peatland development does occur involving extensive substrate removal this would obviously have serious adverse local effects on all populations of small resident animals such as amphibians and reptiles. The long term effects would depend on the landscape rehabilitation practices adopted.

Anything affecting key resource availability would be of importance. In this regard water quality and quantity immediately comes to mind. A significant change in the hydrologic setting of the area due to development would have a major impact on amphibian populations in particular (see section 5.2.2.).

These points are fairly self evident. Anything more specific would be largely speculation. It is the unfortunate truth that only in the wake of development would the more subtle effects of disturbance become apparent.

5.2. Future Work

5.2.1. Funding. Funding for the amphibians and reptiles research program ceases on June 30, 1979 in the middle of the second field season. Considering the framework that has already been established it would be indeed unfortunate if lack of funding forced termination at this time. A proposal has been submitted for funding to cover the last half of the season and preparation of the final report. Funds are required only for travel expenses and salary (see proposal submitted December 1 for details).

The overall goal of the next season would be to elucidate and extend the findings of the first. The proposal noted above lists four main objectives; briefly stated these are: 1) The study of herpetofaunal habitat utilization at an intensively monitored site (Porter Ridge Road). 2) Further experimental work on the relationship between water quality and amphibian reproduction. 3) Breeding ecology of large fens. 4) Overwintering ecology of amphibians in water-saturated peatland conditions.

5.2.2. Water quality. One of the most interesting findings to emerge from this study was the deleterious effect of acidic ombrotrophic-weakly minerotrophic water on frog and toad reproduction. These preliminary findings strongly suggest that these types of studies be extended and other groups (e.g. fish, insects) also be investigated. Crawford in his 1978 DNR peatland water quality report also notes the need for such studies.

My experiments suggest acidity is an important factor in the effects produced by peatland water. However "bog water" is an exceedingly complex chemical solution (Crawford, 1978). The effects of the toxins and nutrients found in this water should also be studied. The elucidation of the potential problems associated with these factors is called for before the delicately balanced hydrologic setting of the peatlands is altered by development.

5.2.3. Continued monitoring. If peatland development is approved on some scale, it is suggested that biologically qualified personnel monitor the development to ascertain deleterious effects.

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I would also like to thank Barbara Coffin for aid in plant identification. Special thanks go to Gerda Nordquist and Mary Engelhard for aid in relevé field work and plant identification.

Fig. 1. Study Area. On the next three pages are three maps:

Fig. 1a.- Eastern Koochiching County
Fig. 1b.- Western Koochiching County
Fig. 1c.- Beltrami County

Specific study areas within this general region are color-coded as follows:

Red dot = approximate location of a trapping fence site
Green areas = observation areas associated with trapping sites
Purple areas = regularly visited observation areas not associated with trapping fence sites

County maps from the Atlas of the State of Minnesota. 1962. Thomas O. Nelson Publishing Co., Fergus Falls, Minnesota.

Fig.1a

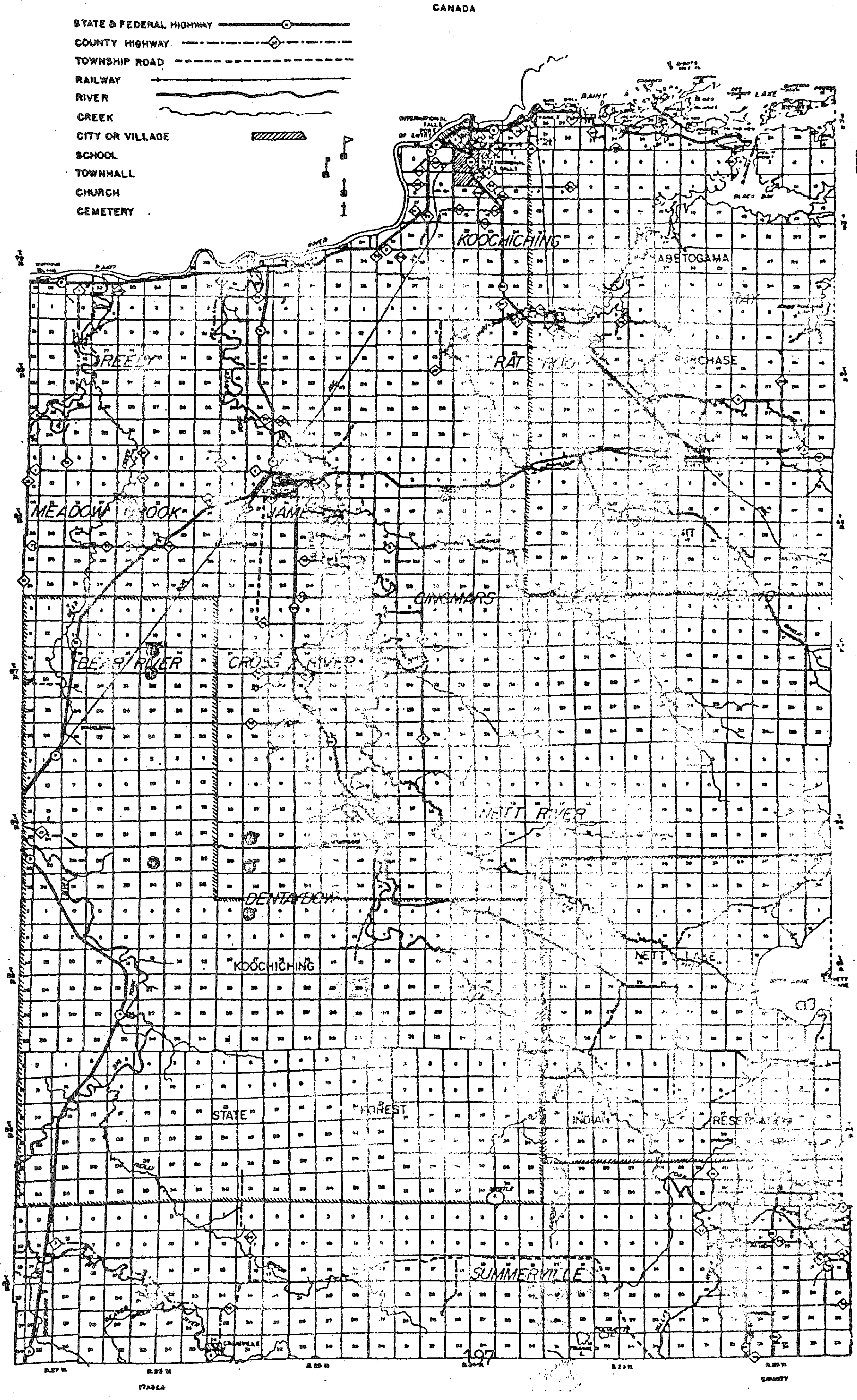
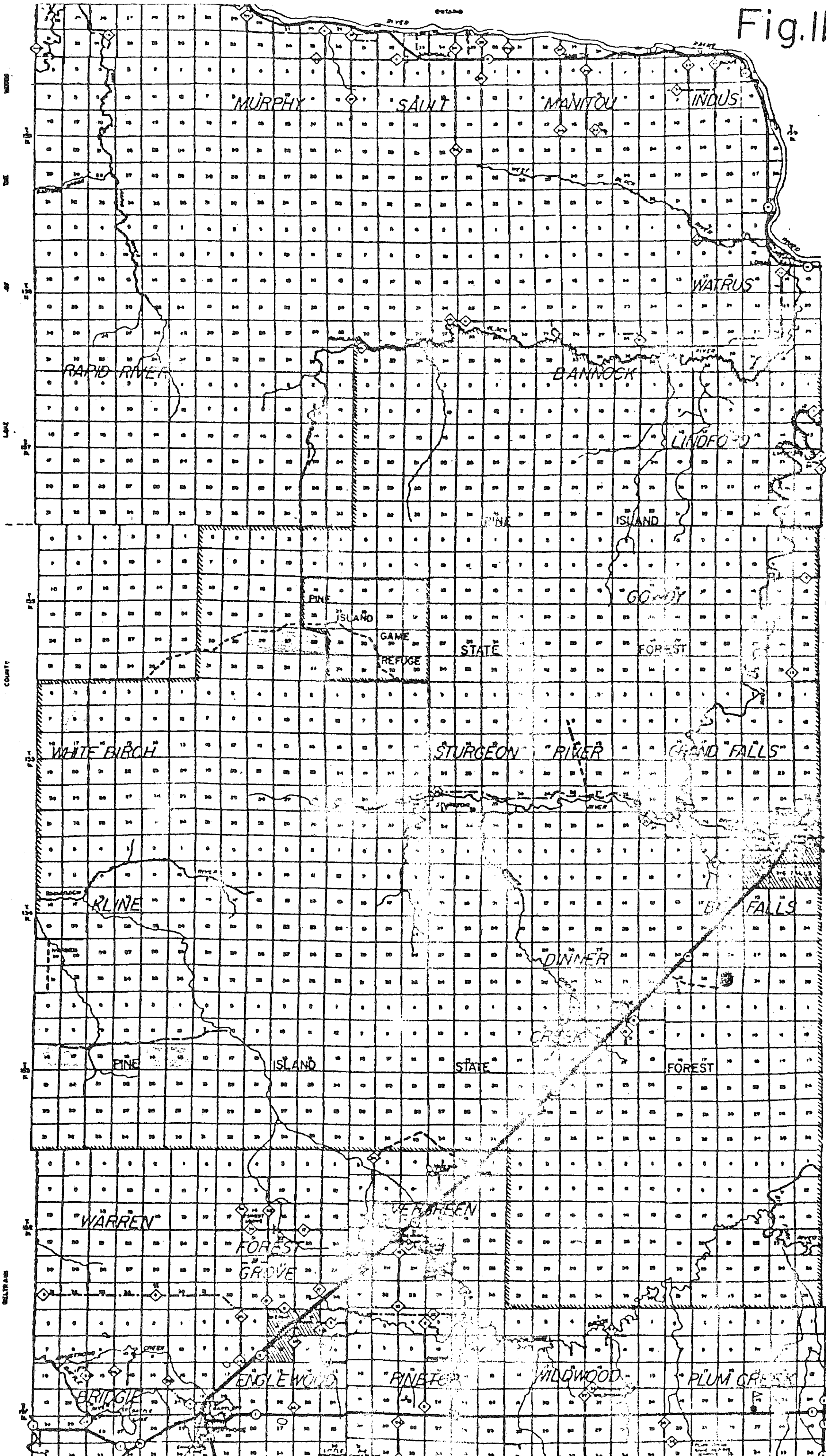
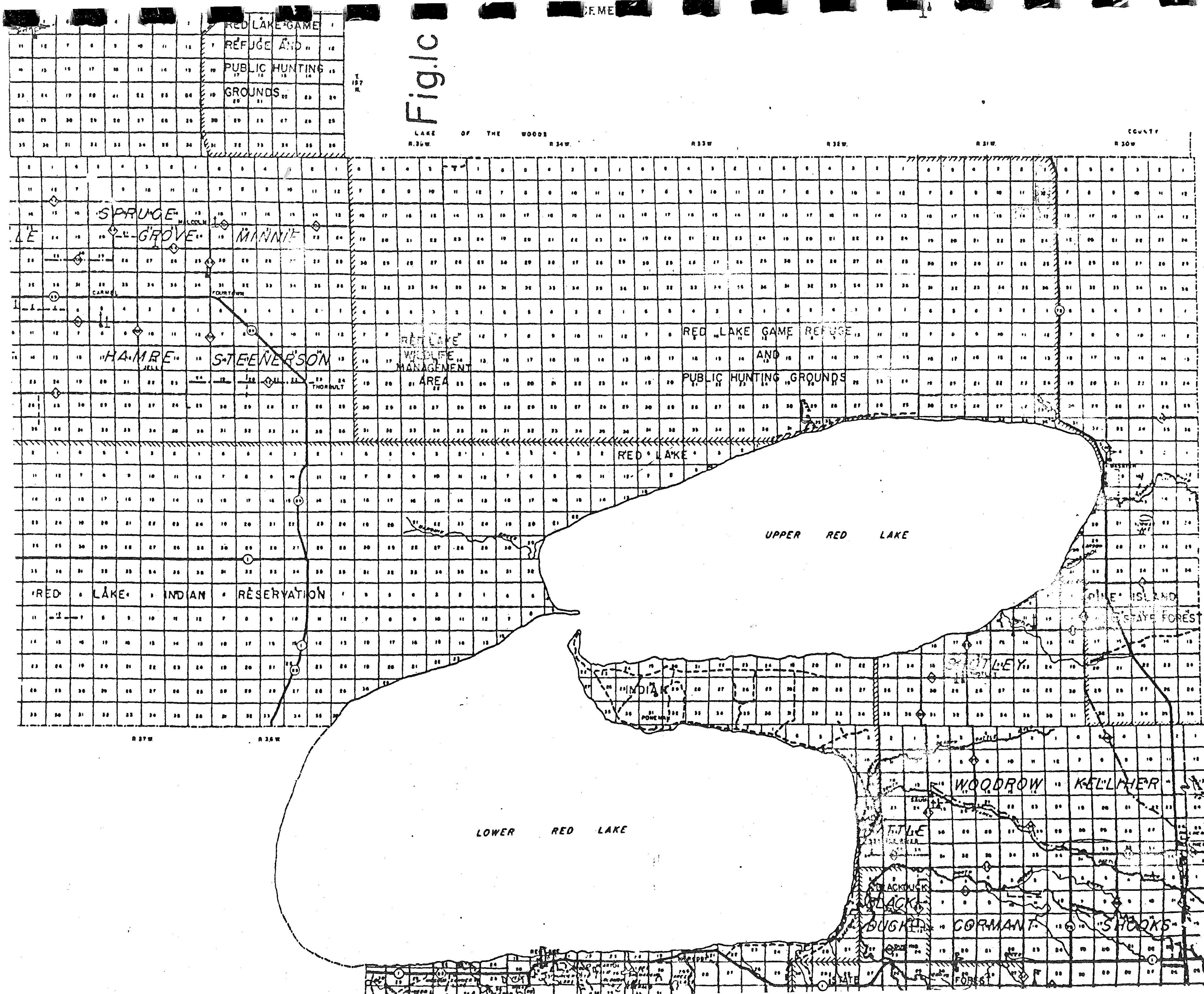

CANADA
STATE & FEDERAL HIGHWAY
COUNTY HIGHWAY
TOWNSHIP ROAD
RAILWAY
RIVER
CREEK
CITY OR VILLAGE
SCHOOL
TOWNHALL
CHURCH
CEMETERY
KOOCHICHING
KABETOGAMA
RAT ROOT
PURCHASE
GREELY
MEADOW BROOK
JAME
CINGMARS
BEAR RIVER
CROSS RIVER
NETT RIVER
DENTAYDOW
KOOCHICHING
NETT LAKE
STATE
FOREST
INDIAN
RESERVATIONS
SUMMERVILLE
ITASCA
ST. LOUIS

Fig.Ib



MURPHY
SAULT
MANITOU
INDUS
WATRUS
RAPID RIVER
BANNOCK
LINDFORD
PINE ISLAND
PINE ISLAND GAME REFUGE
STATE FOREST
WHITE BIRCH
STURGEON RIVER
GRAND FALLS
KLINE
DINNER
CREEK
PINE ISLAND STATE FOREST
WARREN
EVERGREEN
FOREST GROVE
ENGLEWOOD
PINETOP
WILDWOOD
PLUM CREEK
BRIDGIE

Fig.1c



RED LAKE GAME
REFUGE AND
PUBLIC HUNTING
GROUNDS
LAKE OF THE WOODS COUNTY
R 35 W.
R 34 W.
R 33 W
R 32 W.
R 31 W.
R 30 W
SPRUCE
GROVE
MINNIE
CARMEL
FOURTOWN
HAMRE
STEENERSON
THORHULT
RED LAKE
WILDLIFE
MANAGEMENT
AREA
RED LAKE GAME REFUGE
AND
PUBLIC HUNTING GROUNDS
RED LAKE
UPPER RED LAKE
RED LAKE INDIAN RESERVATION
PINE ISLAND
STATE FOREST
SHOTLEY
INDIAN
PONEMAH
WOODROW
KELLIHER
LOWER RED LAKE
BLACKDUCK
CORMANT
SHOOKS
STATE
FOREST
R 37 W
R 36 W

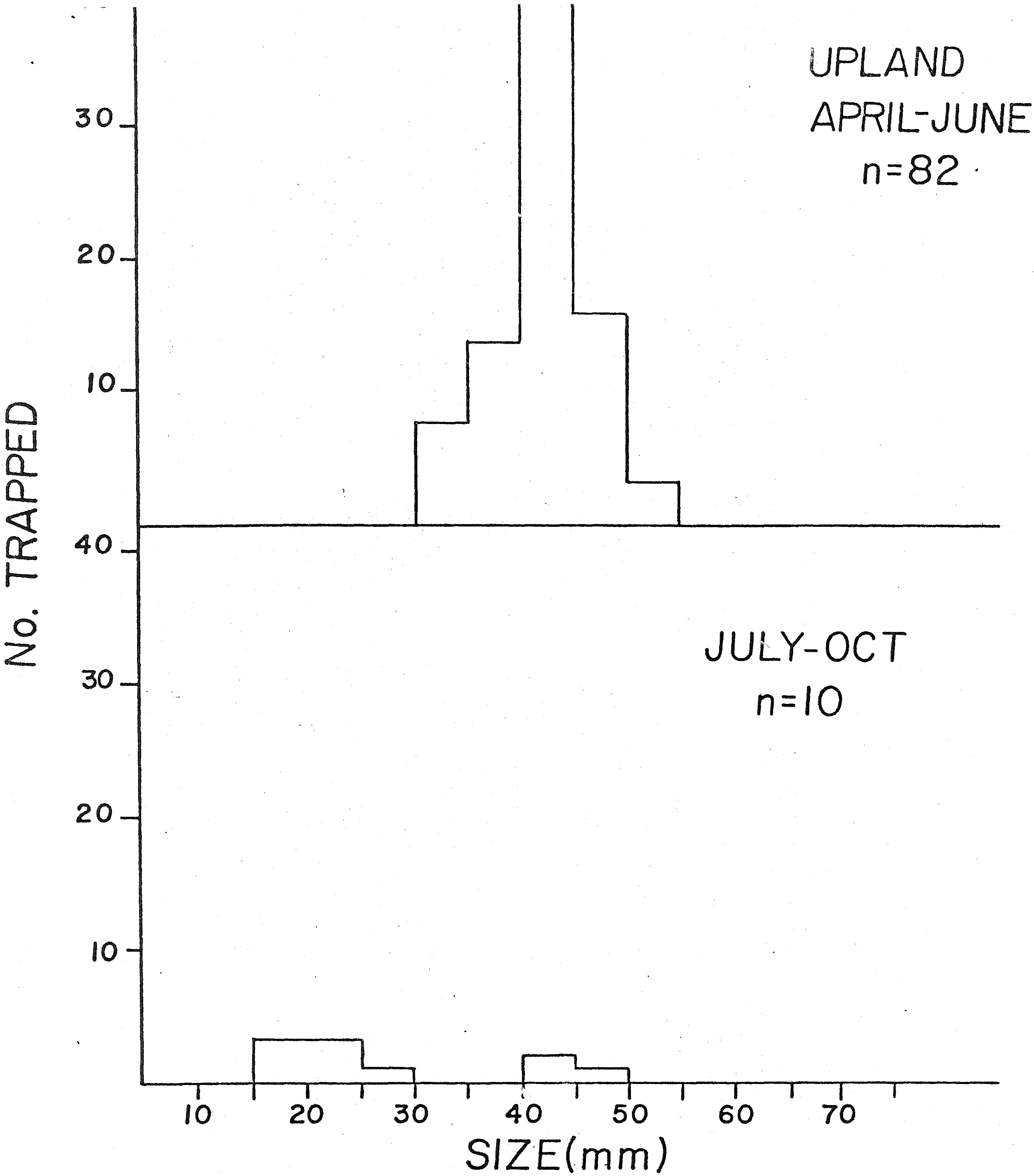


Fig. 2. Rana sylvatica (Wood Frog). Seasonal Movements at Upland Trapping Site (April-October, 1978). See section 3.2.3. for explanation. Minimum adult size (capable of breeding activity): ♂♂ ≈ 38mm; ♀♀ ≈ 40mm.

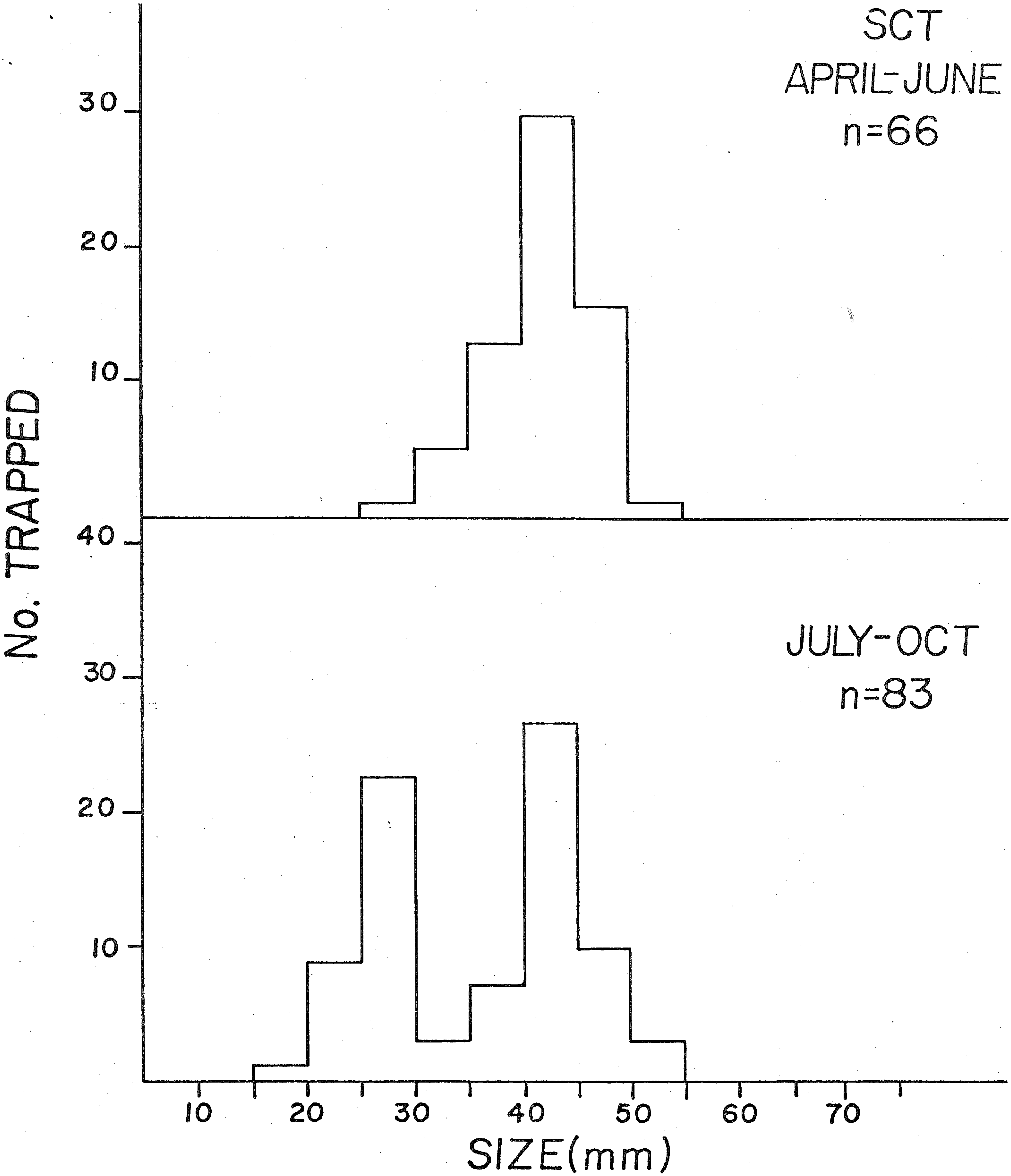


Fig. 3. Rana sylvatica (Wood Frog). Seasonal Movements at Swamp Conifer Tamarack (SCT) Trapping Site (April-October, 1978). See section 3.2.3. for explanation. Minimum adult size (capable of breeding activity): ♂♂ ≈ 38mm; ♀♀ ≈ 40mm.

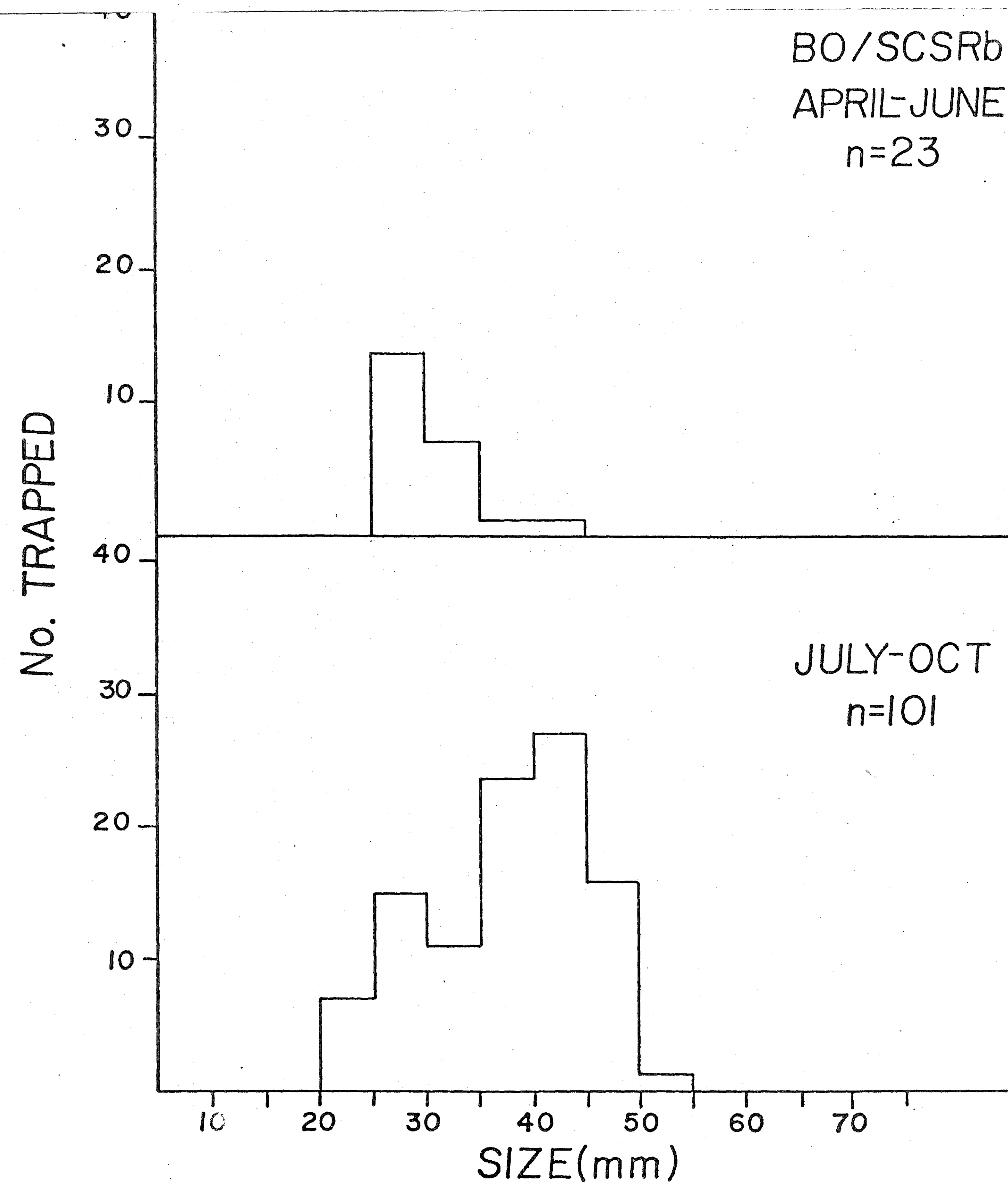


Fig. 4. Rana sylvatica (Wood Frog). Seasonal Movement at Open Bog/Swamp Conifer Spruce-Raised Bog (BO/SCSRb) Trapping Sites (April-October, 1978). See section 3.2.3. for explanation. Minimum adult size (capable of breeding activity): ♂♂ ≈ 38mm; ♀♀ ≈ 40mm.

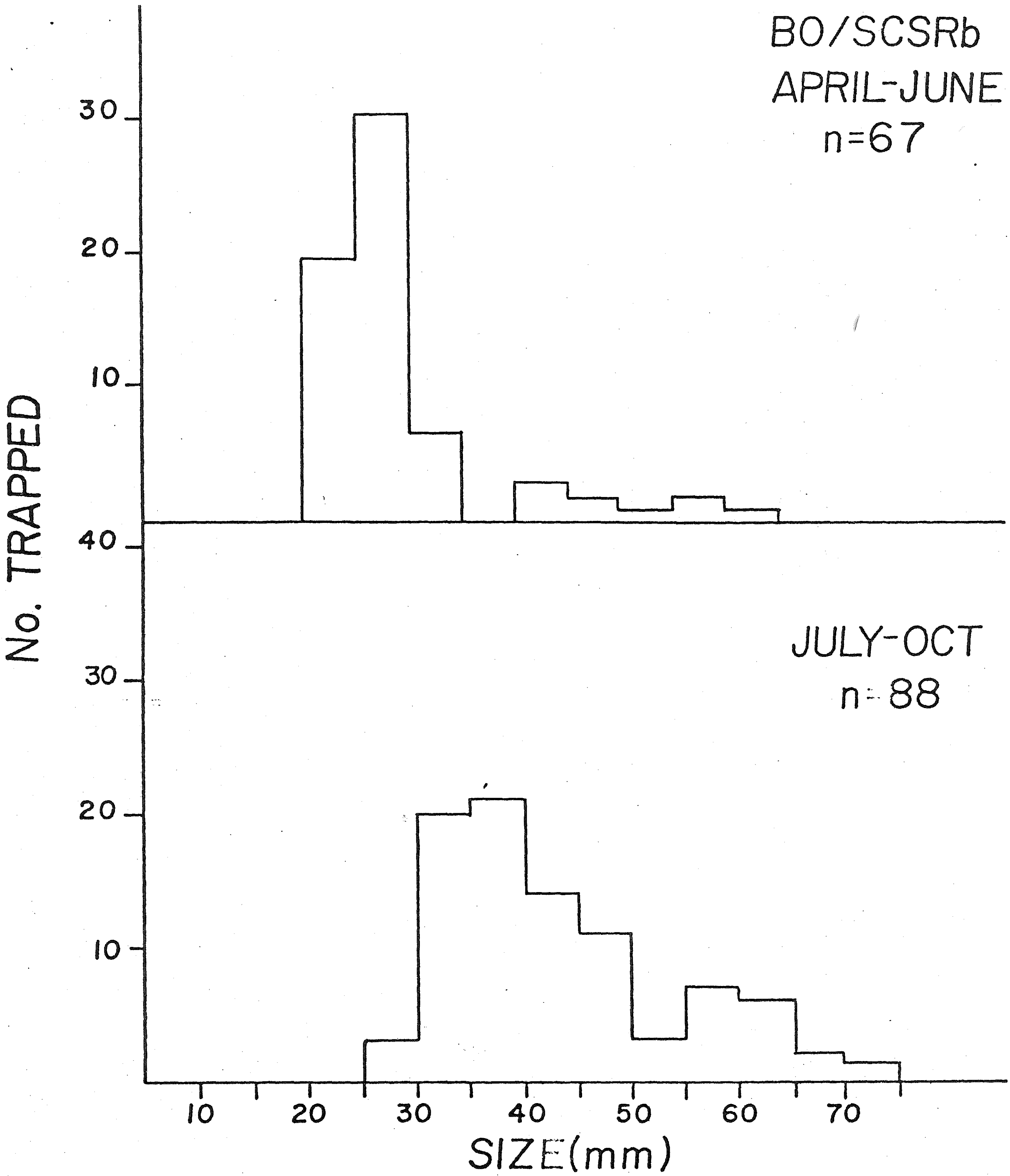


Fig. 5. Bufo a. americanus (American Toad). Seasonal Movement at Open Bog/Swamp Conifer Spruce-Raised Bog (BO/SCSRb) Trapping Sites (April-October, 1978). See section 3.2.3. for explanation. Minimum adult size (capable of breeding activity): ♂♂≈55mm; ♀♀≈ 60mm.

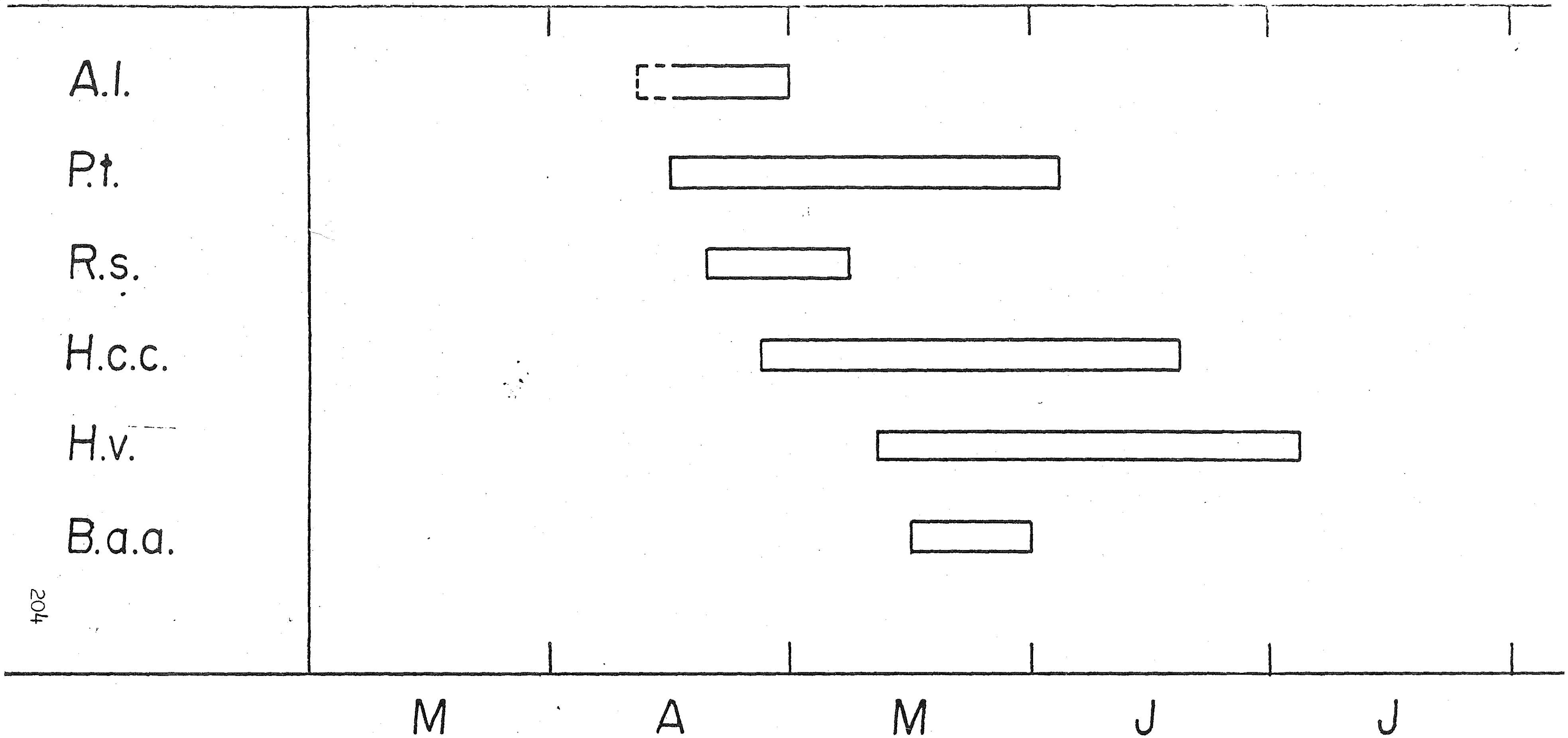


Fig. 6. Approximate Periods of Breeding Activity of Major Peatland Amphibians (March-July, 1978). See section 3. for further discussion. Length of frog and toad periods based on call surveys (section 2.2.3). The salamander Ambystoma laterale (A.l.) does not call. This period is based on observation and dissection information. Species abbreviations are as follows: A.l. = *Ambystoma laterale* (Blue-spotted Salamander); P.t. = *Pseudacris triseriata* (Chorus Frog); R.s. = *Rana sylvatica* (Wood Frog); H.c.c. = *Hyla c. crucifer* (Northern Spring Peeper); H.v. = *Hyla versicolor* (Gray Treefrog); and B.a.a. = *Bufo a. americanus* (American Toad).

Table 1. Check list of the Amphibians and Reptiles of the Peatlands; Central and Southern Koochiching and Western Beltrami Counties, Minnesota.[1]

AMPHIBIANS

Frogs and Toads	
Family Hylidae (Treefrogs)	
Hyla c. crucifer	Northern Spring Peeper
Hyla versicolor[2]	Gray Treefrog
Pseudacris triseriata[2]	Chorus Frog
Family Ranidae (True Frogs)	
Rana sylvatica[2]	Wood Frog
Rana pipiens	Northern Leopard Frog
Family Bufonidae (Toads)	
Bufo a. americanus	American Toad
Salamanders	
Family Ambystomatidae (Mole Salamanders)	
Ambystoma laterale	Blue-spotted Salamander
Family Necturidae (Giant Salamanders)	
Necturus m. maculosus[3]	Mudpuppy

REPTILES

Snakes	
Family Colubridae (Colubrids)	
Thamnophis s. sirtalis	Eastern Garter Snake
Storeria o. occipitomaculata	Northern Red-bellied Snake
Turtles	
Family Emydidae (Water Turtles)	
Chrysemys picta belli	Western Painted Turtle
Family Chelydridae (Snapping Turtles)	
Chelydra s. serpentina[3]	Common Snapping Turtle

[1] This checklist was compiled from specimens collected and observations made during the summer of 1978. These specimens are now deposited in the Bell Museum of Natural History, University of Minnesota.

[2] Taxonomic questions as to the subspecific status of these species remain and are under investigation.

[3] These species were not actually collected but available evidence indicates their presence in the area (Conant, 1975; Breckenridge, 1970; and personal communication with local residents).

Table 2. Check list of the Amphibians and Reptiles of Itasca State Park; Becker, Clearwater, and Hubbard Counties, Minnesota.[1]

AMPHIBIANS	
Frogs and Toads	
Family Hylidae (Tree frogs)	
Hyla c. crucifer	Northern Spring Peeper
Hyla versicolor	Gray Tree frog
Pseudacris t. triseriata	Western Chorus Frog
Pseudacris t. maculata	Boreal Chorus Frog
Family Ranidae (True Frogs)	
Rana clamitans melanota	Green Frog
Rana sylvatica	Wood Frog
Rana pipiens	Northern Leopard Frog
Rana septentrionalis	Mink Frog
Family Bufonidae (Toads)	
Bufo a. americanus	American Toad
Salamanders	
Family Ambystomatidae (Mole Salamanders)	
Ambystoma laterale	Blue-spotted Salamander
Ambystoma t. tigrinum	Eastern Tiger Salamander
Family Salamandridae (Newts)	
Notophthalmus viridescens louisianensis	Central Newt
Family Necturidae (Giant Salamanders)	
Necturus m. maculosus[2]	Mudpuppy
REPTILES	
Snakes	
Family Colubridae (Colubrids)	
Thamnophis s. sirtalis	Eastern Garter Snake
Thamnophis s. parietalis	Red-sided Garter Snake
Storeria o. occipitomaculata	Red-bellied Snake
Opheodrys v. vernalis	Eastern Smooth Green Snake
Opheodrys v. blanchardi	Western Smooth Green Snake
Lizard	
Family Scincidae (Skinks)	
Eumeces s. septentrionalis	Northern Prairie Skink
Turtles	
Family Emydidae (Water Turtles)	
Chrysemys picta belli	Western Painted Turtle
Family Chelydridae (Snapping Turtles)	
Chelydra s. serpentina	Common Snapping Turtle

[1] This checklist was compiled from specimens in the Bell Museum of Natural History, University of Minnesota and specimens collected during the summer of 1964 at Itasca State Park by Dr. W. H. Marshall and J. W. Lang. IBS specimens #1-196 now in the BMNH collection.

[2] This species was not actually collected but available evidence indicates its presence in the area (Conant, 1975; Breckenridge, 1970).

Species \ Habitat	Upland	Open Bog (BO)	Swamp Conifer Spruce-Raised Bog (SCSRb)	Swamp Conifer-Tamarack (SCT)	Swamp Conifer-Spruce (SCS)	Swamp Conifer-Cedar/Spruce (SCC)	Open Fen/Swamp Thicket (FO/ST)	Species Total
Rana sylvatica (Wood Frog)	18.0% (97)	6.9% (37)	16.7% (90)	29.1% (157)	3.9% (21)	6.1% (33)	19.4% (105)	46.0% (540)
Bufo a. americanus (American Toad)	26.3% (127)	11.0% (53)	21.1% (102)	6.4% (31)	20.1% (98)	5.6% (27)	9.3% (45)	41.1% (483)
Pseudacris triseriata (Chorus Frog)	92.4% (73)	0	0	1.3% (1)	0	6.3% (5)	0	6.7% (79)
Ambystoma laterale (Blue-spotted Salamander)	69.0% (20)	6.9% (2)	6.9% (2)	0	3.4% (1)	6.9% (2)	6.9% (2)	2.5% (29)
Hyla c. crucifer (N. Spring Peeper)	70.0% (7)	0	10.0% (1)	10.0% (1)	0	0	10.0% (1)	0.9% (10)
Thamnophis s. sirtalis (E. Garter Snake)	70.0% (7)	10.0% (1)	0	0	20.0% (2)	0	0	0.9% (10)
Rana pipiens (N. Leopard Frog)	25.0% (2)	0	0	0	12.5% (1)	0	62.5% (5)	0.7% (8)
Storeria o. occipitomaculata (N. Red-bellied Snake)	100.0% (8)	0	0	0	0	0	0	0.7% (8)
Hyla versicolor (Grey Treefrog)	100.0% (5)	0	0	0	0	0	0	0.4% (5)
Chrysemys picta belli (W. Painted Turtle)	100.0% (3)	0	0	0	0	0	0	0.3% (3)
Habitat Total	29.5% (349)	7.9% (93)	16.6% (195)	16.2% (190)	10.5% (123)	5.7% (67)	13.5% (158)	100.0% (1175)

Table 3. Peatland Habitat Utilization by Amphibians and Reptiles: Number Collected of Each Species in the Habitats Sampled for the Entire Field Season.
[1] Results given in percentages and actual numbers (in parentheses) for each species and habitat. Both trapping fence and hand collecting data were used in this tabulation.

Species \ Habitat	Upland (131)[2]	Open Bog (BO) (129)	Swamp Conifer Spruce-Raised Bog (SCSRb) (120)	Swamp Conifer-Tamarack (SCT) (112)	Swamp Conifer-Spruce (SCS) (86)	Swamp Conifer-Cedar/Spruce (SCC) (103)	Open Fen/Swamp Thicket (FO/ST) (100)	Species Total
Rana sylvatica (Wood Frog)	0.69 (91)	0.28 (36)	0.75 (90)	1.40 (157)	0.24 (21)	0.32 (33)	1.04 (104)	0.68 (532)
Bufo a. americanus (American Toad)	0.69 (91)	0.41 (53)	0.85 (102)	0.28 (31)	1.03 (89)	0.26 (27)	0.44 (44)	0.56 (437)
Pseudacris triseriata (Chorus Frog)	0.49 (64)	0	0	0.01 (1)	0	0.03 (3)	0	0.09 (68)
Ambystoma laterale (Blue-spotted Salamander)	0.15 (19)	0.02 (2)	0.02 (2)	0	0.01 (1)	0.02 (2)	0.02 (2)	0.04 (28)
Rana pipiens (N. Leopard Frog)	0	0	0	0	0.01 (1)	0	0.05 (5)	0.008 (6)
Storeria o. occipitomaculata (N. Red-bellied Snake)	0.05 (6)	0	0	0	0	0	0	0.008 (6)
Hyla c. crucifer (N. Spring Peeper)	0.02 (2)	0	0.01 (1)	0.01 (1)	0	0	0.01 (1)	0.006 (5)
Thamnophis s. sirtalis (E. Garter Snake)	0	0.01 (1)	0	0	0.01 (1)	0	0	0.003 (2)
Habitat Total	2.08 (273)	0.71 (92)	1.63 (195)	1.70 (190)	1.31 (113)	0.63 (65)	1.56 (156)	1.39 (1084)

Table 4. Peatland Habitat Utilization by Amphibians and Reptiles: Number Collected of Each Species per Day in the Habitats Sampled for the Entire Field Season.[1]

[1] These results were calculated by taking the total number of specimens caught in a given habitat type and dividing by the total number of days the trapping fence in that habitat was open. Only data from trapping fences were used in this calculation. Number in parentheses under each calculation is the actual number caught.

[2] The number in parentheses under each habitat type is the number of days the trapping fence in that habitat was in operation.

Habitat / Month	May	June	July	August	May-August $\overline{X}$ pH
Porter Ridge Road-Raised Bog Drain	4.14	4.47	4.04	4.17	4.21
Open Bog (BO)*	4.62	4.44	4.59	4.55	4.55
Swamp Conifer Spruce-Raised Bog (SCSRb)*	4.99	4.42	4.83	4.63	4.72
Upland*	5.7	5.2	5.2	DRY	5.37
Open Fen/Swamp Thicket (FO/ST)*	5.5	5.7	5.3	5.45	5.49
Porter Ridge Road-Open Fen	5.43	5.45	5.90	5.79	5.64
Waskish-Open Fen	5.98	6.0	6.1	6.04	6.03
Swamp Conifer-Spruce (SCS)*	6.38	5.8	6.2	6.4	6.20
Swamp Conifer-Tamarack (SCT)*	6.2	6.35	6.2	6.1	6.21
Porter Ridge Road-Upland Pool	6.63	6.6	6.6	5.93	6.44
Swamp Conifer-Cedar (SCC)*	7.1	6.9	6.9	7.0	6.98
Wisner Road-Upland Pool	7.15	7.0	6.8	DRY	6.98
Waskish-Fen Ditch	6.32	8.2	6.9	6.6	7.01

Table 5. Mean pH Values for Various Sites in the Study Area from May-August, 1978. The number of measurements taken at a site for a given month varied from 2-6. They were always consistent at a given site. The total $\overline{X}$ pH at a given site for the 4 month period is given in the last column. Sites are listed from most acidic to most basic. See section 3.3.1. for further comments and interpretation.
*=trapping fence site

Water Treatment	Upland Pool	Bog	Neutralized Bog	Tap	Acidified Tap
$\overline{X}$ pH	6.85	4.27	6.83	7.93	4.32
No. Eggs	150	185	178	170	187
Hatching Success* (after 14 days)	150 (100.0%)	0 (00.0%)	173 (97.2%)	169 (99.4%)	8 (4.3%)

Table 6. Egg Hatching Experiment: *Bufo a. americanus* (American Toad). See section 3.3.4. for methods and interpretation. The following comments and statistical analysis apply to both the *B. a. americanus* (above) and *H. c. crucifer* (Table 7.) experiments. The results presented are a condensation of data; two batches of eggs were tested in each treatment for both species. The results from these batches have been combined for a given treatment. *Statistical analysis: A single classification analysis of variance (ANOVA) showed a highly significant ($P < 0.001$) added variance component due to treatment effects among treatments. A sum of squares simultaneous test procedure (SS-STP) showed that the Bog and Acidified Tap treatments significantly reduced hatching success compared to the circumneutral treatments (tests from Sokal and Rohlf, 1969).

Water Treatment	Upland Pool	Bog	Neutralized Bog	Tap	Acidified Tap
$\overline{X}$ pH	6.8	4.24	7.02	8.02	4.35
No. Eggs	24	77	52	70	70
Hatching Success* (after 11 days)	10 (41.7%)	0 (0.00%)	44 (84.6%)	60 (85.7%)	0 (0.00%)

Table 7. Egg Hatching Experiment: *Hyla c. crucifer* (Northern Spring Peeper). See section 3.3.4. for methods and interpretation.
*See Table 6. for comments and statistical analysis.

Species: *Rana sylvatica* (Wood Frog)	Water Treatment Upland Pool	Bog	Species: *Bufo a. americanus* (American Toad)	Water Treatment Upland Pool	Bog
$\overline{X}$ pH	6.74	4.15	$\overline{X}$ pH	6.56	4.12
No. Tadpoles	94	86	No. Tadpoles	86	64
Tadpole Survivorship* (after 18 days)	80 (85.1%)	2 (0.02%)	Tadpole Survivorship (after 24 hrs.)	86 (100.0%)	0 (00.0%)

Table 8. Tadpole Survivorship Experiments: *Rana sylvatica* (Wood Frog) and *Bufo a. americanus* (American Toad). See section 3.3.4. for methods and interpretation. *Statistical analysis: A 2x2 test of independence was done using the G-Statistic. The null hypothesis that tadpole survivorship is independent of water treatment is rejected (tests from Sokal and Rohlf, 1969).

LITERATURE CITED

Allee, W. C., Emerson, A. E., Park, O., Park, T. and Schmidt, K. P. 1950 Principles of Animal Ecology. Saunders, Philadelphia.

Bellis, E. D. 1957. An Ecological study of the frog Rana sylvatica Le Conte. Ph.D. Thesis, University of Minnesota.

_______. 1959. A study of movement of American toads in a Minnesota bog. Copeia 1959(2):173-174.

_______. 1965. Home range and movements of the wood frog in a northern bog. Ecology 46:90-98.

Breckenridge, W. J. 1944. Reptiles and Amphibians of Minnesota. Univ. of Minn. Press, Minneapolis, 20? pp., 3rd printing, 1970.

Bury, R. B. 1977. Sampling herpetological communities by a removal method. Paper presented at the 1977 joint annual meeting of the Herpetologists' League--Society for the Study of Amph. and Rep.

Cobb, B. 1963. A Field Guide to the Ferns. Peterson Field Guide Series. Houghton Mifflin Co., Boston.

Conant, R. 1975. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. 2nd Ed. Houghton Mifflin Co., Boston.

Crawford, R. L. 1978. Effects of peat utilization on water quality in Minnesota. DNR Peatland Research Program Final Report.

Dunson, W. A., et al. 1973. Survival of brook trout in a bog-derived acidity gradient. Ecology. 54(6):1370-1376.

_______. 1977. Exceptional tolerance to low pH of some tropical black water fish. J. Exp. Zool. 201:157-162.

Ewert, M. A. 1969. Seasonal Movements of the Toads Bufo americanus and B. cognatus in Northwestern Minnesota. Ph.D. Thesis, University of Minnesota.

Fox, R., Malterer, T. and R. Zarth. 1977. Inventory of peat resources in Minnesota. Dept. of Natl. Res., State of Minn., St. Paul.

Glaser, P. 1977. Terrestrial vegetation and wildlife supplement draft environmental impact statement. Minn. Power and Light Co.--Proposed Unit 4 (Clay Boswell steam electric station).--Appendix B-Vegetation.

Gleason, H. A., and Cronquist, A. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. D. Van. Norstrand Co., N.Y.

Gorham, E. 1976. Acid precipitation and its influence upon aquatic ecosystems--an overview. Water, Air, and Soil Pollution. 6:457-481.

Gosner, K. L. and I. H. Black. 1957. The effects of acidity on the development and hatching of New Jersey frogs. Ecology 38(2):256-262.

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

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

Hodge, R. P. 1976. Amphibians and Reptiles in Alaska, the Yukon and Northwest Territories. Alaska Northwest Publishing Co., Anchorage, Alaska.

Morley, T. 1969. Spring Flora of Minnesota. Univ. of Minn. Press, Minneapolis.

Neill, W. T. 1974. Reptiles and Amphibians in the Service of Man. Indianapolis: Bobbs-Merrill.

Noble, G. K. and Noble, R. C. 1923. The Anderson tree frog, observations on its habits and life history. Zoologica. 2:417-455.

Porter, K. R. 1972. Herpetology. W. B. Saunders Co.

Pough, F. H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, Ambystoma muculatum. Science 192:68-FO.

Savage, R. M. 1961. The Ecology and Life History of the Common Frog. Sir Isaac Pitman & Sons, Ltd., London.

Schmidt, W. D. 1965. Aspects of the water economies of nine species of amphibians. Ecology 46(3):261-269.

Smith, H. M. 1978. A Guide to Field Identification: Amphibians of North America. Golden Press, N.Y.

Sokal, R. R. and Rohlf, F. J. 1969. Biometry. W. H. Freeman, San Francisco.

Voght, R. C. and R. L. Hine. 1977. Development and evaluation of techniques for assessment of impact of highway development on wildlife populations and habitats in the uppermidwest (Amphibians and Reptiles). Dept. Natl. Res., Madison, WI. In Press.

APPENDIX

HABITAT ANALYSIS

Contents

APPENDIX

I. HABITAT ANALYSIS: RELEVÉS

METHODS

The primary source of information on the amphibians and reptiles of the peatlands for this report was a series of trapping sites employing 50 foot aluminum fences armed with pitfall and funnel traps (drift fences). These were placed at seven sites, each one selected on the basis that it was representative of a major peatland habitat type. Relevés were done at each of these trapping fence sites. I have followed with certain modifications the general relevé format described by Glaser (1977). APPENDIX Table 1A describes the details of the system employed. Also the HABITAT section of each relevé has been somewhat expanded. In a telegraphic style, I have tried to convey a general impression of that habitat, using common names and emphasizing features of herpetofaunal importance. This is intended specifically for non-botanists reading the report. Nomenclature for general peatland vegetation types follows the Fox et al., Minnesota Peat Inventory scheme. Locations refer to U.S. Geological Survey 1: 24000 ortho photo quadrangle maps. Botanical nomenclature follows Gleason and Crondquist (1963), Cobb (1963) and Morley (1969). These relevés are preliminary in the sense that plant identification to desired taxonomic levels remains to be done for certain plants. I would like to thank Barbara Coffin and Gerda Nordquist for aid in plant identification and relevé field work.

APPENDIX I
Table 1A

RELEVÉ KEY

Height Classes

8	>35 m
7	20-35 m
6	10-20 m
5	5-10 m
4	2-5 m
3	0.5-2 m
2	0.1-0.5 m
1	< 0.1 m

NOTE: After each species listed, three numbers appear. These refer to Coverage, Abundance, and Sociability of the plants listed, in that order. Under a given height class, species are listed in order of importance on the basis of these three factors.

Coverage

1	< 5%
2	5-25%
3	25-50%
4	50-75%
5	> 75%

Abundance

0	single occurrence
1	rare
2	few individuals
3	common
4	very numerous

Sociability

1	growing singly
2	grouped, few individuals
3	large group, many individuals
4	small colonies, extensive patches, broken mat
5	extensive mat

RELEVÉ 1

UPLAND

DATE: August 24, 1978

LOCATION: Johnson Landing NE, Minn: T66N, R25W, Sect. 20, SW quarter

HABITAT: Mixed upland hardwood-conifer forest dominated by Jack pine, Quaking Aspen, and Paper Birch. Rich shrub and forb understory dominated by Amelanchier, Hazelnut, Willow, ferns, and Blueberry. Located on a lake-washed ground moraine. Well drained sandy soil. This upland borders a small fen to the south. Narrow transition zone of Bog Birch, Iris, and Willow into open fen dominated by sedges, reed grasses, and rushes. Water in fen up to 2-3 feet deep in spots in spring. Level drops as summer progresses. By August a central wet channel remains, but no real open water. During spring this fen is an extremely active frog breeding site.

SAMPLE PLOT: 400 sq m

Height Class 6, cover 50-75%

Populus tremuloides 3:3:1
Pinus banksiana 3:3:1

Height Class 5, cover 5-25%

Populus tremuloides 2:2:1
Betula papyrifera 1:0:1

Height Class 4, cover 5-25%

Ostrya virginiana 2:2:1
Populus tremuloides 1:2:1
Picea glauca 1:0:1
Abies balsamea 1:0:1
Betula papyrifera 1:0:1
Salix spp. 1:0:1
Amelanchier spp. 1:0:1

Height Class 3, cover 50-75%

Amelanchier spp. 3:3:1
Corylus americana 2:3:2
Salix spp. 2:3:2
Pteridium aquilinum 2:3:1
Populus tremuloides 2:2:1
Prunus spp. 1:2:1
Abies balsamea 1:2:1
Picea mariana 1:2:1
Rosa spp. 1:0:1
Lonicera spp. 1:0:1

Height Class 2, 50-75% cover

Pteridium aquilinum 4:4:1
Vaccinium spp. 3:3:3
Gramineae: tall, broad blade 3:3:2
Prunus spp. 2:2:1
Amelanchier spp. 2:2:1
Abies balsamea 1:2:1
Pinus banksiana 1:2:1
Diervilla lonicera 1:2:1
Leguminosae 1:2:1
Rosa spp. 1:2:1
Ledum groenlandicum 1:2:2
Aralia nudicaulis 1:2:1
Populus tremuloides 1:2:1
Corylus americana 1:2:1
Lonicera spp. 1:2:1
Equisetum spp. 1:2:1
Picea mariana 1:0:1

Height Class 1,> 75%

Maianthemum canadense 2:4:1
Lycopodium tristachyum 2:3:3
Neckera spp. (feather moss) 2:3:2
Cornus canadensis 2:3:1
Antennaria spp. 2:2:2
Linnea borealis 1:3:1
Gaultheria procumbens 1:2:1
Chimaphila umbellata 1:2:2
Pyrola spp. 1:2:1
Trientalis borealis 1:2:1
Anemone quinquefolia 1:2:1

RELEVE 1
UPLAND

Height Class 1, >75% (cont.)

Vaccinium spp. 1:2:1
Galium spp. 1:2:1
Abies balsamea 1:2:1
Aster spp. 1:1:1
Clintonia borealis 1:0:1
Solidago spp. 1:0:1
Polytrichum spp. present

RELEVÉ 2 & 3

OPEN BOG (BO)
and
SWAMP CONIFER SPRUCE-RAISED BOG (SCSRb)

DATE: August 25, 1978

LOCATION: Little fork SW, Minn.: T67N, R27W, Sect. 15, NE quarter

HABITAT: Note: This site is located at the edge of a large peatland area which exhibits the classic radiating pattern of a raised bog. Two trapping fences were installed at this location about 200 yards apart in very different habitat types. One is in open bog which grades into a rather dense Black Spruce grove where the other fence is set. These fence sites are the points around which the following relevés were done. These sites are located approximately 1/4 mile south of Wisner Road which is built on a lake-washed ground moraine with upland mixed conifer-hardwood forest.
OPEN BOG: Large opening about 600 yds wide and a 1/4 mile long. Occasional stagnant Tamarack and Black Spruce. Continuous carpet of low relief sphagnum hummocks and hollows covered with ericaceous shrubs and Cotton grass. The forbs Buckbean and Three-leaved False Solomon's Seal are also numerous. Very wet site with much standing water except during very dry periods. Sphagnum peat.
BLACK SPRUCE-RAISED BOG: Dense stagnant Black Spruce grove (50 x 300 yds). Fades into open bog to the north and less dense muskeg to the east, west and south. Falling and rotting trees numerous in grove. Large sphagnum hummocks (often centered on the bases of trees) with water filled channel-like network of hollows. Understory dominated by sedges, Labrador Tea, Marsh Cinquefoil, and Three-leaved False Solomon's Seal. Very wet shady site. Standing water always present in hollows. Sphagnum peat.

SAMPLE PLOT: 100 sq m
(for both relevés)

OPEN BOG

Height Class 4, < 5%

Larix laricina 1:2:1

Height Class 3, 5-25%

Eriophorum spp. 3:4:4
Larix laricina 2:3:1
Picea mariana 1:2:2

Height Class 2, 25-40%

Eriophorum spp. 4:4:4
Larix laricina 1:3:1
Picea mariana 1:2:2

Height Class 1, > 75%

Sphagnum spp. 5:4:5

Height Class 1, > 75% (cont.)

Smilacina trifolia 4:4:4
Menyanthes trifoliata 3:4:4
Kalmia polifolia 3:4:3
Vaccinium oxycoccos 3:4:3
Chamaedaphne calyculata 3:3:3
Sarracenia purpurea 2:3:4
Polytrichum spp. 2:3:4
Andromeda glaucophylla 2:3:2
Larix laricina (seedlings) 1:2:2
Picea mariana (seedlings) 1:2:2
Usnea spp. (on trees)

SWAMP CONIFER SPRUCE-RAISED BOG

Height Class 6, < 5%

Picea mariana 1:2:1

RELEVÉ 2 & 3

OPEN BOG (BO)
and
SWAMP CONIFER SPRUCE-RAISED BOG (SCSRb)

SWAMP CONIFER SPRUCE-RAISED BOG (cont.)

Height Class 5, 25-50%

Picea mariana 3:3:2

Height Class 4, 25-50%

Picea mariana 3:4:3

Height Class 3, 5-25%

Betula pumila 3:3:2
Picea mariana 3:3:2
Juncus spp. 1:0:1

Height Class 2, 5-25%

Carex spp. (medium broad leaf) 3:3:3
Ledum groenlandicum 3:3:3
Potentilla palustris 3:3:2
Eriophorum spp. 2:3:4
Chamaedaphne calyculata 2:3:2
Picea mariana 1:2:2
Salix spp. 1:2:2
Kalmia polifolia 1:2:1

Height Class 1, > 75%

Sphagnum spp. 5:4:5
Vaccinium oxycoccos 3:4:3
Ledum groenlandicum 2:3:1
Smilacina trifolia 4:4:4
Chamaedaphne calyculata 1:3:2
Picea mariana 1:3:2
Kalmia polifolia 1:2:1
Andromeda glaucophylla 1:2:1

RELEVÉ 4

SWAMP CONIFER-TAMARACK (SCT)

DATE: August 24, 1978

LOCATION: Johnson Landing NE, Minn. T66N, R25W, Sect. 29, SW quarter.

HABITAT: Stagnant Tamarack swamp. Numerous falling and rotting trees. Upper understory very shrubby with Bog Birch and Willow. Sedges abundant. Large sphagnum hummocks (often centered on bases of trees) dominated by ericaceous shrubs. Very tangled appearance. Hollows form irregular network of water filled channels. Very wet site. Standing water always present. Sphagnum-sedge peat with numerous woody inclusions.

SAMPLE PLOT: 400 sq m

Height Class 5, 25-50%

Larix laricina 3:3:1
Picea mariana 2:2:1

Height Class 4, 5-25%

Salix spp. 2:2:1
Picea mariana 1:2:1

Height Class 3, 75-100%

Carex spp. (fine) 5:4:5
Betula pumila 4:4:4
Salix spp. 2:3:2
Gramineae (broad, long leaf) 2:2:1
Typha latifolia 1:3:1
Ledum groenlandicum 1:2:2
Chamaedaphne calyculata 1:2:2
Carex spp. (broad)1:2:2
Picea mariana 1:2:1
Larix laricina 1:2:1
Iris spp. 1:2:1

Height Class 2, 50-75%

Ledum groenlandicum 3:3:2
Chamaedaphne calyculata 3:3:2
Andromeda glaucophylla 3:3:2
Potentilla palustris 2:3:2
Betula pumila 2:2:1
Kalmia polifolia 1:2:2
Equisetum spp. 1:2:2
Salix spp. 1:2:1
Larix laricina 1:1:1
Picea mariana 1:1:1

Height Class 1, 75-100%

Sphagnum spp. 5:4:5
Smilacina trifolia 3:4:1
Vaccinium oxycoccos 2:4:2
Calla palustris 1:3:1
Neckera spp. (feathermoss) 1:2:2
Rubus spp. 1:2:2
Ledum groenlandicum 1:2:2
Betula pumila 1:2:1
Chamaedaphne calyculata 1:2:1
Andromeda glaucophylla 1:2:1
Solidago spp. 1:2:1
Salix spp. 1:1:1
Picea mariana 1:1:1

RELEVÉ 5

SWAMP CONIFER-SPRUCE (SCS)

DATE: August 24, 1978

LOCATION: Johnson Landing NE, Minn.: T66N, R25W, Sect. 29, NW quarter.

HABITAT: Stagnant Black Spruce forest. Many falling and rotting trees. Continuous carpet of irregular sphagnum hummocks and hollows dominated by ericaceous shrubs. Density and robustness of Black Spruce varies considerably over the general area ranging from patches of open bog to dense Black Spruce stands. Water table just below the surface, however, site relatively dry in appearance with little or no surface water visible. Sphagnum peat.

SAMPLE PLOT: 400 sq m

Height Class 5, 5-25%

Picea mariana 2:2:1
Larix laricina 1:2:1

Height Class 4, 50-75%

Picea mariana 4:3:2

Height Class 3, 50-75%

Picea mariana 3:3:2
Chamaedaphne calyculata 2:3:2
Ledum groenlandicum 2:3:1
Vaccinium spp. 1:2:1
Carex spp. (fine blade) 1:0:1

Height Class 2, > 75%

Ledum groenlandicum 4:4:4
Chamaedaphne calyculata 3:3:3
Carex spp. 2:3:2
Picea mariana 2:2:1
Kalmia polifolia 2:2:1
Andromeda glaucophylla 1:2:1
Vaccinium spp. 1:2:1

Height Class 1, 100%

Sphagnum spp. 5:4:5
Vaccinium oxycoccos 2:3:2
Vaccinium vitis-idaea 2:3:1
Vaccinium spp. 1:2:1
Neckera spp. (feathermoss) 1:3:2
Ledum groenlandicum 1:2:2
Polytrichum spp. 1:2:2
Cladonia rangiferina 1:2:2
Kalmia polifolia 1:1:1
Picea mariana 1:1:1
Usnea spp. (on trees)

RELEVÉ 6

SWAMP CONIFER-CEDAR/SPRUCE (SCC)

DATE: August 24, 1978

LOCATION: Johnson Landing NW, Minn.: T66N, R26W, Sect. 27, NE quarter.

HABITAT: Northern White-Cedar swamp. Many falling and rotting trees. Many partially uprooted trees still growing. Very tangled appearance. Substrate of moss and sedge covered mounds. Rich understory of shrubs, forbs, and grasses dominated by Dogwood, Alder, Labrador Tea, and Three-leaved False Solomon's Seal. Moderately shady site with scattered sun flecks. Relatively wet site with standing water in hollows and small depressions most of the time. Sphagnum-sedge peat with many woody inclusions.

SAMPLE PLOT: 400 sq m

Height Class 6, 5-25%

Picea mariana 2:2:1
Thuja occidentalis 1:0:1

Height class 5, > 75%

Thuja occidentalis 5:4:1

Height Class 4, 25-50%

Thuja occidentalis 2:2:1
Fraxinus nigra 2:2:1
Abies balsamea 2:2:1
Alnus rugosa 1:2:1

Height Class 3, 25-50%

Thuja occidentalis 2:3:2
Cornus racemosa 2:3:2
Alnus rugosa 2:3:2
Abies balsamea 2:2:1
Fraxinus nigra 1:2:1
Ribes spp. 1:2:1

Height Class 2, > 75%

Carex spp. (tussock) 4:4:4
Ledum groenlandicum 2:3:2
Caltha palustris 2:3:2
Gramineae (sidebranch) 2:3:2
Carex spp. (broad) 1:2:3
Cornus racemosa 1:2:2
Cypripedium acaule 1:2:2

Height Class 2, > 75% (cont.)

Carex spp. (medium tussock) 1:2:2
Lycopodium spp. 1:2:2
Abies balsamea 1:2:1
Aster spp. 1:2:1
Lonicera hirsuta 1:2:1
Aralia nudicaulis 1:2:1
Botrychium virginianum 1:2:1
Dryopteris spp. 1:2:1
Equisetum spp. 1:2:1
Impatiens biflora 1:2:1
Salix spp. 1:0:1
Gramineae (tall) 1:0:1
Mentha arvensis 1:0:1

Height Class 2, 75-100%

Neckera spp. (feathermoss) 4:4:4
Smilacina trifolia 3:4:1
Sphagnum spp. 2:4:4
Cornus canadensis 2:3:1
Rubus spp. 2:3:1
Mitella nuda 2:3:1
Gaultheria hispidula 1:3:2
Coptis trifolia var. groenlandica 1:2:2
Viola spp. 1:2:2
Linnea borealis 1:2:2
Trientalis borealis 1:2:1
Aster macrophyllus 1:2:1
Galium spp. 1:2:1
Maianthemum canadense 1:2:1
Vaccinium oxycoccos 1:1:2
Thuja occidentalis (seedling) 1:1:1
Picea mariana (seedling) 1:1:1

RELEVÉ 6

SWAMP CONIFER-CEDAR/SPRUCE (SCC)

Height Class 2, 75-100% (cont.)

Abies balsamea 1:1:1
Vaccinium vitis-idaea 1:1:1
Lichens on *trees*, dead logs, etc.

RELEVÉ 7

OPEN FEN/SWAMP THICKET (FO/ST)

DATE: August 29, 1978

LOCATION: Big Falls SE, Minn.: T154N, R25W, Sect. 33, SE quarter

HABITAT: Mosaic of extensive patches of open fen and swamp thicket. Open fen dominated by thick sedge growth. Very wet site. Plants mostly grow out of the water. Occasional patches of above water substrate (small sphagnum mounds, clumps of dried sedge tussocks). Swamp thicket dominated by dense Speckled Alder. Shrubs form base for sphagnum and other moss accumulation. More above water substrate visible. Water level fluctuates with rainfall but always very wet habitat. Sedge peat with many woody inclusions.

SMAPLE PLOT: 100 sq m

OPEN FEN (FO)

Height Class 3, > 75%

Carex spp. (medium width leaf) 5:4:5
Rumex spp. 2:3:1
Alnus rugosa 2:2:1
Umbelliferae 1:2:1

Height Class 2, 50-75%

Carex spp. (esp. old dried tussocks) 4:4:4
Hypericum spp. 3:4:1
Scutellaria galericulata 2:3:1
Onoclea sensibilis 2:3:1
Lycopus uniflorus 1:3:1
Alnus rugosa 1:2:2
Campanula spp. 1:2:1
Galium spp. 1:2:1
Polygonum spp. 1:2:1
Equisetum spp. 1:2:1

Height Class 1, 50-75%

Calla palustris 2:3:3
Hypericum spp. 2:3:1
Campanula spp. 1:3:1
Sphagnum spp. (very clumped) 1:3:3
Lycopus uniflorus 1:2:1
Onoclea sensibilis 1:2:1
Dryopteris cristata 1:2:1
Osmunda cinnamomea 1:2:1

SWAMP THICKET (ST)

Note: As mentioned in the habitat description above, this area was a mosaic of open fen and relatively dense swamp thicket dominated by Alder. The understory of these patches of swamp thicket was not thoroughly surveyed, however, many elements of the open fen flora were seen in both areas. 10 yards to the north of the open fen relevé plot a large patch of this thicket abruptly began. The following major differences can be noted:

Height Class 5, < 5%

Larix laricina (occasional)

Height Class 4, > 75%

Alnus rugosa 3:4:4

Height Class 3, >75%

Alnus rugosa 4:4:4
Carex spp. 4:4:4

Height Class 2, 5-25%

Ledum groenlandicum 1:3:2
Sphagnum spp. (clumped at base of shrubs)

Month (Temperature in °C) Habitat	April	May	June	July	August	Sept.	April-Sept. $\overline{X}$ pH
Upland	15.4	19.6	22.2	26.8	DRY	DRY	21.0
Open Fen/ Swamp Thicket (FO/ST)	---	15.0	17.3	20.6	17.7	12.5	16.6
Swamp Conifer-Tamarack (SCT)	10.5	14.0	16.1	19.1	17.4	14.9	15.3
Open Bog (BO)	---	13.0	15.4	17.2	17.6	10.7	14.8
Swamp Conifer-Cedar/Spruce (SCC)	---	9.5	12.4	15.8	15.4	15.5	13.7
Swamp Conifer Spruce-Raised Bog (SCSRb)	---	6.5	13.0	16.2	15.6	10.9	12.4
Swamp Conifer-Spruce (SCS)[1]	---	---	8.0	10.4	9.7	11.7	10.0

II. Habitat Analysis: Microclimate. Table 2A. Mean Monthly Daytime Microhabitat (standing water) Temperatures (°C) (April-September 1978). Temperatures listed (from top) in order of decreasing overall (April-Sept.) mean temperature. Temperatures taken from standing water (sun and shade) at the seven trapping fence sites from 9AM-4PM under a variety of weather conditions each month. Each monthly measurement based on *6 measurements per month (varied from 5-13 measurements at a given site each month).

[1]Standing water was not usually present in this habitat. Temperature was taken from ground water which seeped into the pitfall cans of the trapping fence. These cans were buried 14" deep in the sphagnum substrate. Note the stable low temperatures.

Measurement / Month	Maximum Temperature (°C)		Minimum Temperature (°C)		Precipitation (cm)
	$\bar{X}$	Range	$\bar{X}$	Range	
April	12.2	(-1.1-23.3)	-2.7	(-8.9-4.4)	3.51
May	23.4	(12.2-31.1)	5.2	(-5.6-16.1)	8.99
June	25.0	(14.4-32.8)	8.1	(-1.7-13.9)	4.80
July	26.6	(22.2-31.7)	11.3	(5.0-15.6)	14.48
August	27.2	(17.8-34.4)	10.4	(3.3-21.1)	14.83
Sept.	19.8	(11.1-33.9)	8.5	(0.0-19.4)	8.61

III. Habitat Analysis: Climate. Table 3A. Mean Monthly Maximum/Minimum Air Temperature (°C) and Monthly Rainfall (cm) data (April-September, 1978). Data compiled from measurements taken at the Big Falls Forestry Station, Big Falls, Koochiching County. Data collected by Forestry Technician, John Lumpio.

SECTION F

AGRICULTURAL

RECLAMATION of PEATLANDS

Progress Report No. 4

Oct. - Nov. - Dec. 1978

Submitted to: Department of Natural Resources
State of Minnesota

by: Soil Science Dept.
U. of M.
St. Paul, Mn. 55108

Submitted by Rouse S. Farnham

The first two weeks of October were dedicated to completing the bed preparation of the grass plots in the northeast corner of the excavation area. At this depth of excavation much of the woody detritus is evident, more so than appears in the top eighteen inches as revealing with surface rotating. These woody remnants consist of undecomposed roots and stumps of native trees and greatly impede the workability of the soil. Some rotators used in surface tilling are designed to force such detritus deeper, to a depth of less significance. The rotovator and tractor were not used in this instance due to plot size and proximity to ditch, and the extreme wetness of the soil. It should be noted that in order to most efficiently drain this area, a combination of permanent drainage system (covered tiles) and a pumped sump-reservoir would be recommended. The present system does not sufficiently drain the interior, due to constant caving prohibiting the flow of water. The method of tilling used was the hand-operated garden tiller. The plots were tilled to a depth of about one foot, with the woody remnants worked to the surface. The aisle area between the plots was also tilled, as was the through-way to the remainder of the excavated area, plotting out four 10 x 40 foot plots. The more stubborn stumps were removed by hand with a prybar. The woody pieces were then raked away from the plots. From the center aisle and the through-way between the plots about eight inches of the tilled peat was moved to build beds in each of the four plots. The beds were then raised about two inches above the original surface and further isolated by a shallow peripheral ditch. This isolation further optimizes water relations.

During the third week of October these beds were prepared for seeding. After raking to level, 300#/A 6-24-24 fertilizer was applied to each of the four beds. This fertilizer was lightly raked in and then the plots were rolled to insure a uniform, packed seed bed. NK 200 perennial ryegrass and Park Kentucky bluegrass were selected from the surface trials to be planted.

These varieties exhibited the best responses to the conditions and methods applied. Two plots of each variety were sown. The seeding rate was about 25 ounces/plot. The seed was gently raked in to allow sufficient soil contact. It should be noted that the soil was dry and precipitation was minimal. These low moisture conditions, coupled with the onset of the cooler, shorter-day season, were unfavorable to seed germination. In effect, this is dormant seeding. Germination should be evident early spring after the thaw.

At the close of the season, the water level in the ditches and the sump-reservoir indicated that the height of the water table would not impede development in the excavation area next spring. As soon as weather permits, pumping must be resumed to accomodate melt water, otherwise a flooded condition will persist. That condition would eliminate any germination and greatly hinder any development.

The week of October 23-27 was spent south of the garden plots in an unplanted area between the fence and the grain trial area. Several hundred asparagus plants were donated by the horticulture department to be planted at our discretion. Four seventy foot ditches, five feet apart, were plotted and dug one spade in width, fifteen inches in depth. The dense root mats were washed and separated into individual propagules. Asparagus is commonly planted in early spring from greenhouse cuttings, however we intended to overwinter this crop in rows. The propagules were situated in the ditch every three feet, then covered with six inches of soil. The ditch was then filled with a hay mulch. This procedure should insure safe overwintering of the asparagus. After spring thaw the hay mulch is removed and replaced by a few inches of peat, still allowing a depression in which to water and designate the row. This crop should be harvested during the '79 season.

The following week (Oct. 30 - Nov. 3) marked the completion of the harvest. The remaining crops which yielded produce of any value were potatoes, cauliflower, cabbage, onions and carrots. The head lettuce and spinach were of little value. Due to the failure of certain crops a varietal trial is advised. The potato crop yielded 170-190# or about 30#/row of 60'. The number of tubers per plant is a better indication in view of the early July planting. Every plant had four to eight tubers. Size of each tuber, again, was not outstanding. These potatoes were about "new potato" size, russet-type, 1½ inch diameter at best. Earlier planting, a varietal trial and frost tenting would greatly increase all aspects of yield. All but six or eight of the entire population of cauliflower plants produced heads. These heads steadily decreased in size and quality as the season drew to a close. The varying degrees and rates of development, and the growth habits of the variety (especially blanching characteristics) indicated more than one variety. The yield was not ascertained due to several harvests, though the ratio of quality heads to plants indicates moderate success. The cabbage crop was also untrue to variety. These crops were donated by a local commercial grower, as were the potatoes and onions. All cabbage plants produced heads, but of varying maturation (size and firmness of head). The onion crop was of marginal success, due to early soil conditions. By the time soil moisture decreased to a suitable level, the season was changing to unfavorable. The carrots yielded about five fifty-pound sacks. Variety of shapes, rooting habits and an insignificant amount of aster yellows contributed to their status as commercial, that is, not of table quality.

Some observations were recorded as this season drew to a close. Field preparation is of utmost importance. This includes optimum drainage, total weed eradication, surface contouring (uniformly), raised planting beds and proper soils fertility maintenance. The importance of an early start is evident, preferably mid to late May. Last season's results justify the necessity of varietal trials per vegetable crop. In this way, varieties may be selected to allow a more broad harvesting schedule, and the varieties most apt to produce an optimum quantity of quality produce may also be selected. A more diverse array of vegetable crops may be chosen, and certain of those proven could be planted on a larger scale, simulating commercial procedures.

After the harvest was complete and the refuse was moved away, the north side of the enclosure was removed. The rotovator could then be used inside the fence. The entire garden area was tilled to a depth of one foot. Along the east and west sides peat was removed and deposited in the center of the garden as a ridge. Then the sides were back-bladed to the center and rotovated overall. Thus the garden area was contoured for next season.

The remainder of field 7W was eradicated of existing weeds. The area south of the grain-grass plots (about three acres) was sprayed with Round-Up in two applications, insuring desired results. This area was then rotovated. The grain-grass plots were the only areas remaining untilled, for the purpose of noting overwintering abilities of the crops. A contract was negotiated by the State for ditching and clearing of existing ditches, to proceed throughout the winter months.

The project was resumed at the University with the onset of winter. The first stage of developments was modifying lab and greenhouse bay and corresponding with both seed sources and local horticulturalists. The lab was updated by purchasing equipment for sample preparation, sample storage, and physical-chemical analysis of samples. Each peat sample will be subjected to the following procedures in our lab: bulk density, moisture content, ash content, fiber content, calorimetric combustion, pH (both in $CaCl_2$ and in distilled water), Kjeldahl nitrogen digestion-distillation, and sample preparation for ICP emission spectroscopy (Inductively Coupled Plasma, of

Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, Hg, As, Co, B). The greenhouse bay modifications include designing automatic watering beds for replicated nutrient applications and for germination of transplants. We intend to experiment with optimum macro and micro nutrient applications to several indicator plants in surface and excavated soils. Early this spring crops that will be transplanted and will be germinated and grown under our care. We can then have more confidence in varietal trueness and quality of transplants. We will be dealing with a number of the 21 businesses contacted, attempting six to eight varieties of each vegetable in the enclosed garden area. These crops should number twelve to fifteen, including some exotic, novelty crops. The forage, grass and grain crops will be changed minimally. The growing area will include nearly all of field 7W and replicated for the most part in the excavated area. This winter's experiments characterizing the media and nutrient applications should prove beneficial in all aspects of plot research next growing season.

SECTION G

Forestry Reclamation of Peatlands in Northern Minnesota

Progress Report No. 4

October 1 - December 31, 1978

Unmined Peatlands

No field work is expected during the winter. Applications of herbicides will be made in late spring to control unwanted vegetation in the plantings at Zim.

Mined Peatlands

Preliminary plans have been arranged to test several combinations of fertilizers and tree species on "excavated" peat areas at Zim. Seedlings are being arranged for and should be planted in late May or early June depending upon weather conditions.

Secondary Succession on Disturbed Peatlands

Laboratory and office analysis continues on approximately 350 samples collected during the 1978 field season.

Greenhouse - Laboratory Study

Preliminary plans are to employ a graduate research assistant beginning in June 1978 utilizing the University of Minnesota College of Forestry greenhouses at St. Paul for the study.

SECTION H

ECOLOGICAL AND FLORISTIC STUDIES OF THE PEATLAND VEGETATION OF NORTHERN MINNESOTA

1978 PROGRESS REPORT

by

Eville Gorham

Herbert E. Wright, Jr.

Paul H. Glaser

Gerald A. Wheeler

15 December 1978

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SUMMARY

Four major plant communities have been recognized in the extensive peatland complex north of Upper Red Lake, which exhibits strongly patterned landscape features of fen water tracks, crested bogs with radiating ridges of spruce, and large, ovoid bog "islands" with a rim of spruce and an open center. The *Carex trisperma-Vaccinium vitis-idaea* association is found in the forested areas of the ombrotrophic bogs, which receive their mineral supply solely from the atmosphere. The *Carex oligosperma* association is observed in the open bog areas with only scattered dwarf trees. The *Triglochin maritima-Drosera intermedia* community occupies the pools in minerotrophic fen water tracks carrying water which has percolated through mineral soil. The *Carex paupercula-Calla palustris* association dominates the tear-drop shaped tamarack islands in the fen water tracks. Hummocks in the fens exhibit a mixture of pool and island species.

Ditching and roadbuilding across the peatland have led to flooding upstream and drying out downstream, with consequent effects upon the vegetation. Drying out has had a particularly marked effect upon the fen water tracks. Moderate drying intensifies the ridge-and-trough pattern which is oriented across the direction of water flow, because it encourages colonization of the ridges by dwarf birch. Severe drying obliterates the pattern, because the dwarf birch then colonized troughs as well.

Vascular plant collections number 590, and have been deposited in the herbarium of the University of Minnesota. These collections yielded 198 taxa, representing 104 genera in 50 plant families. Eight taxa are of special interest because they have not been collected hitherto in Minnesota or are very rare in the state, and because they represent extreme western stations for these taxa in the United States or even in North America. One hundred and twenty-nine taxa represent new records for Beltrami and Koochiching Counties. In addition, 16 of the taxa recorded in this study are regarded as rare or endangered plants in Minnesota.

Analysis of water chemistry has shown that the ombrotrophic bogs occupy acid sites (pH 3.7-4.6) poor in mineral salts, and that the relatively stagnant waters are highly colored and rich in dissolved organic matter. The minerotrophic fen sites are generally slightly acid to circumneutral (pH 5.0-7.0), and are on average about twice as rich in mineral salts. Because these waters are flowing along the fen water tracks, they are generally less colored, with much lower concentrations of dissolved organic matter. A major hydrologic question raised (but not yet answered) in this study is the origin of the minerotrophic water which supports fen plant communities in water tracks well within the main complex of ombrotrophic crested bogs and large, ovoid bog islands.

Stratigraphic studies, although not pursued as actively as the other investigations, have revealed deep peat throughout most of the wetland, with the greatest depths in the crested ombrotrophic bog and the least in the upstream part of the western fen water track which branches north and south just west of the central bog complex.

Research to date has provided a great deal of information about the floristics and ecology of the Red Lake bogs and fens, but many gaps remain in our understanding of their form and function, which is vital to any efforts at their protection or reclamation. In order to fill these gaps the following research program is recommended:

(1) Detailed studies of the effect of ditching and road-building upon plant communities and vegetation pattern.

(2) Detailed examination of the unditched and relatively pristine peatland east of Highway 72 and northeast of Waskish, which may be the area most suitable for protection and preservation.

(3) Vegetational and floristic studies of the wetland communities bordering the peatland and probably of considerable importance to wildlife.

(4) Comparative studies of large peatlands in northeastern Minnesota, which do not exhibit the strong patterns characteristic of the Red Lake peatland.

(5) Stratigraphic studies to elucidate the developmental history of the fens and bogs and provide information which should be of great assistance in their protection or reclamation.

(6) Analysis of the role of fire in the forested bogs.

(7) Further studies of water and peat chemistry in order to elucidate the sources and patterns of water flow, which

largely control the differentiation of minerotrophic fens and ombrotrophic bogs.

(8) Investigation of rates of peat accumulation in fens and bogs, to see whether peat is still being laid down, and if so, what rates of peat accretion are characteristic of the different landforms and plant communities. Such information may be of great significance for peatland reclamation.

1.0 INTRODUCTION

1.1 Objectives

The primary objective of the research in 1978 has been to establish a classification of the plant communities and the landscape units (cf. Heinselman 1970) of the large patterned peatlands of northwestern Minnesota as a basis for mapping them. "Ground truth" of the kind provided in certain specific areas by this study is essential to an adequate program of broad-scale mapping based on interpretation of aerial photographs. A secondary but still very important objective has been to increase our presently inadequate understanding of (a) the inter-relationships among the plant communities, (b) the development of landscape patterns, and (c) the environmental control of development and succession of plant communities and landscape units. The fundamental environmental factors are topography, hydrology, and the chemistry of the underlying soil, but vegetation development itself modifies the action of these factors in diverse ways that are not well understood.

Understanding of the kind we seek will be of the utmost importance not only to the preservation and management of more or less pristine peatlands but also to the reclamation and management of those peatlands utilized by man, whether as energy resources or for horticulture, agriculture, forestry, or wildlife.

1.2 Focus of the proposal

Research in 1978 has been focused on the complex peatland north of Upper Red Lake, in northeastern Beltrami County and parts of adjacent counties. It is by far the largest and most distinctive continuous peatland in Minnesota and the entire northern United States (except for Alaska), and consists of a complex mixture of "ombrotrophic" bogs, whose surfaces receive water only from atmospheric precipitation, and "minerotrophic" fens, which receive in addition water that has its source in adjacent or subjacent mineral soil.

The Red Lake peatland owes its origin to the poor drainage over the very large area of gentle slope formerly occupied by Glacial Lake Agassiz, plus its location within the boreal conifer forest, where the cool summer climate inhibits the decomposition of dead plant material that accumulates on the ground surface. Although not quite so large as the Everglades of southern Florida, which is protected as a National Park, it is just as sensitive to the regime of water flow from adjacent areas, and in fact it contains more distinctive and more diversified vegetation patterns than the Everglades.

The unique complex of vegetation patterns so conspicuous on aerial photographs of the Red Lake peatland reflects the delicate relations between plants and their moisture and nutrient tolerances. These relations are more clearly manifested than in the vegetation of most upland terrain, which is strongly influenced as well by diversified topography and soils. The ecological responses are also more obvious than in the case of lakes, where the daily and seasonal water movements, both lateral and vertical, keep the system in such a state of flux that distributional patterns of organisms are not easy to work out -- and the organisms themselves are predominantly microscopic and thus not obvious in the field. The simpler relations in the Red Lake peatland make it an ideal area for ecological studies on a grand scale.

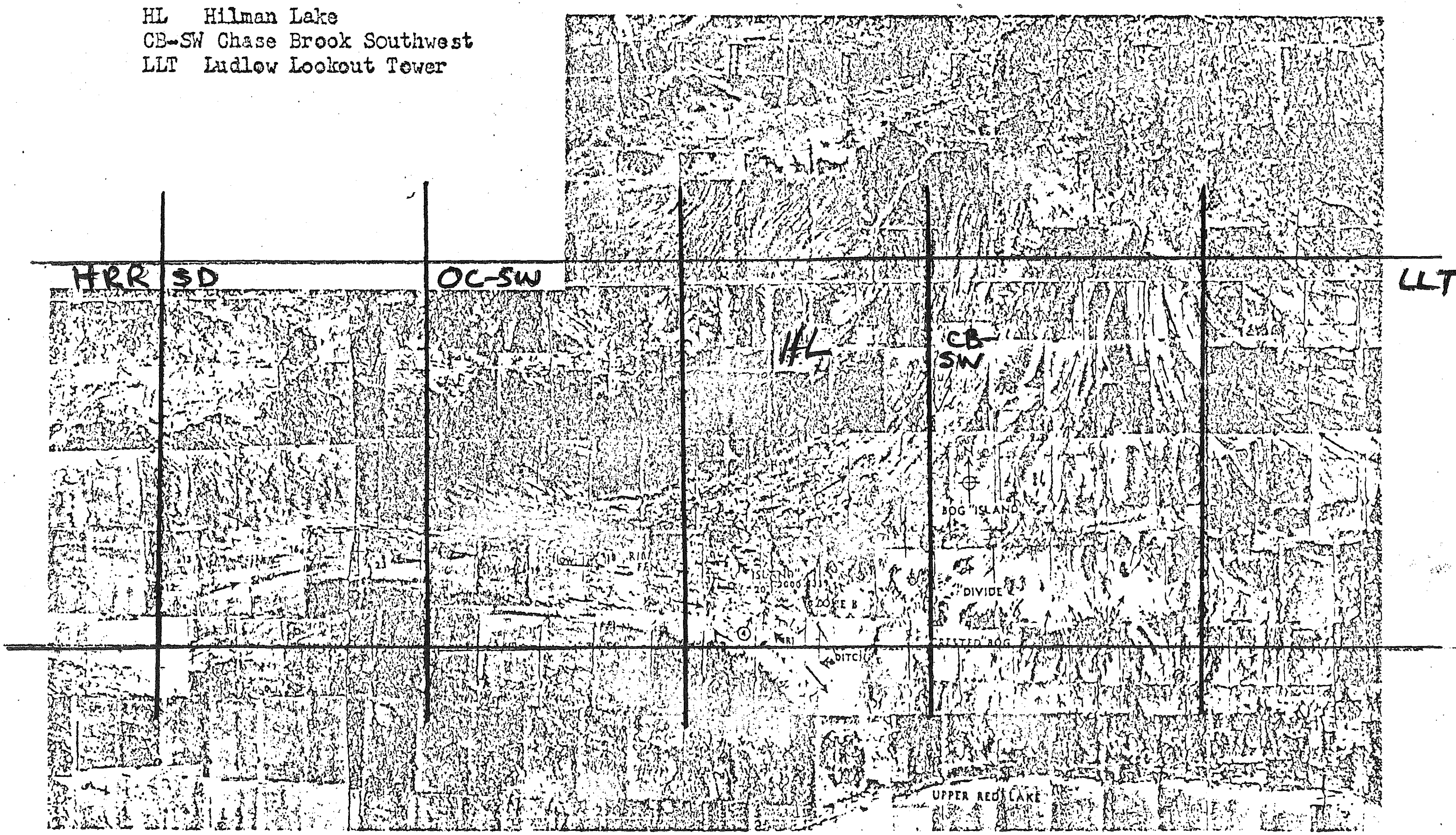
The entire Red Lake peatland can be subdivided broadly into four areas, most of which are shown on the attached airphoto mosaic (Figure 1):

(1) The western part consists of a single water track about 2 miles wide carrying nutrient-rich water from the upland on the west (Head of Rapid River quadrangle map of U.S. Geological Survey) eastward for about 20 miles through the Shilling Dam and Oaks Corner Southwest quadrangles into the Hilman Lake quadrangle. This water track is fed as well by many parallel flow lines coming in from the northwest. It is a great, largely treeless sedge fen, characterized by a pattern of sinuous linear ridges and pools transverse to the direction of water flow. The ridges have a lush growth of sedge plants and sphagnum mosses and even some shrubs like dwarf birch, whereas the pools have sparser and smaller sedge plants along with water plants like <u>Menyanthes</u>. This "ribbed fenland" resembles the well-known string bogs of the boreal forests of Canada and Scandinavia, but the origin of the Minnesota patterns is uncertain (Hofstetter 1969). The treeless fenland is

FIGURE 1

U.S. Geol. Survey topographic maps:

HRR Head of Rapid River
SD Shilling Dam
OC-SW Oaks Corner Southwest
HL Hilman Lake
CB-SW Chase Brook Southwest
LLT Ludlow Lookout Tower



locally interrupted by small forested islands that have a streamlined form -- a blunt head of trees (tamarack, black spruce, and/or cedar) at the upstream end and a long tail of dwarf birch extending downstream. An island probably starts as a small obstruction to surface-water flow along the water track, e.g. by a clump of dwarf birch shrubs with a few tamarack trees. Diversion of the nutrient-rich water around the obstruction allows the clump to enlarge, especially through the growth of sphagnum mosses, which flourish in nutrient-poor settings. Studies of peat cores taken on and adjacent to the islands imply that the fenland started as a wet meadow about 3000 years ago as the climate became wetter, and that the little islands have developed later (Griffin 1975, 1977).

The region encompassing the main western watertrack has been studied thoroughly by Hofstetter (1969) and Griffin (1975, 1977), and so has been given less attention in 1978 than the areas whose descriptions follow in items (2), (3), and (4).

(2) In the Hilman Lake quadrangle this great water track splits eastward into two portions, one leading southward to Upper Red Lake, the other leading northward to the Rapid River, a tributary of the Rainy River. The feature that splits the water track is the central portion of the Red Lake Peatland -- a complex of large ovoid areas bordered on the south close to Upper Red Lake by a large linear raised bog with typical radiating pattern of spruce clumps. A raised bog is a gentle dome resulting from upward peat growth. It receives moisture and

nutrients only from precipitation, for it is circumvented by the nutrient-rich waters that come from the uplands. The large ovoid areas, themselves seen best on the Chase Brook Southwest quadrangle (Figure 2), may also be raised bogs, crowded together by the development of narrow water tracks (with string patterns) between them. General flow in the water tracks is northward, and the ovoid areas are generally attenuated to the north. Most of the ovoid areas, however, do not show the pattern of radiating spruce clumps that is characteristic of many raised bogs. Instead they have a rather homogeneous cover of spruce, which commonly is sparse near the center of each area. This very distinctive pattern of pointed ovoid areas may be unique in patterned peatlands -- at least such forms occur nowhere else in Minnesota and are not known to have been described elsewhere in the world. The details of their vegetation and chemistry, together with those of the water tracks between them, have been the major focus for study in 1978.

(3) East of the complex of ovoid patterns is another broad water track, which leads westward on the Ludlow Lookout Tower quadrangle toward the central area and then north to the Rapid River. It also has a ribbed pattern as well as tree islands with tails. This section is transected from south to north by the Waskish road (Rt. 72) but otherwise is uninterrupted except by the ill-fated drainage ditches of 1914, which also penetrate the central area and part of the western area. Some sites within this area have been studied in 1978.

(4) In the northeastern corner of the continuous peatland is another area of raised bogs (east of Figure 1), with associated ovoid areas developed to the northeast as the surface water heads in that direction toward the Black River. Some sites have been studied here too in 1978.

At the margins of these major fen and bog areas are fen communities dominated by shrubs (alder, willow, etc.) and trees (tamarack and mixed swamp hardwoods). These marginal communities deserve attention because of their suitability as habitat for deer and moose, and for a variety of smaller mammals and birds, which may utilize both these areas and the adjacent upland areas on mineral soil. However, because of their transitional status, it was felt that their study should await the accumulation of detailed information on the major landforms and plant communities of the main peatland.

The total expanse of the Red Lake peatland as delimited is about 50 miles from west to east and 9 miles from south to north -- thus about 450 sqaure miles or 285,000 acres. It is terminated on the east by the Black River and the tributaries of the Big Fork River, which have worked back headward to the south to erode the peatland. East of the Big Fork River, however, are several smaller peatlands, also on the bed of Glacial Lake Agassiz. The largest of these is Myrtle Lake Bog, which has been designated a National Landmark because of its fine display of raised bogs and patterned fens, whose plant communities and water chemistry have been studied by Heinselman (1970).

This presumably was once continuous with Red Lake peatland before the dissection by the Big Fork River and its tributaries. Peat cores indicate that it started formation earlier than the western part of Red Lake peatland (Janssen 1968), and a case can be made for gradual western expansion of peatlands from east to west as the late climate has become cooler and wetter in the last few thousand years.

2.0 METHODS

2.1 Analysis of plant communities

The relevé has been employed, as described by Dr. Paul Glaser. "Semi-quantitative methods seem to provide the best approach for a rapid and yet precise vegetation survey. The best known and most widely used semi-quantitative method of vegetation classification is the relevé method developed by the Braun-Blanquet school of phytosociology. This relevé method stresses the total floristic composition of different vegetation types. Visual estimates are made of the cover (abundance) and sociability (dispersion) for each species. Classification is based on relevés which are written descriptions of the location, environment, and total species composition of a uniform stand of vegetation. The relevés are then arranged into a phytosociological table so that the patterns of species distribution within the relevés can be utilized to delimit plant communities or associations. Associations are defined by character species which are restricted to a particular vegetation type. These character species then are used to organize a hierarchical classification of vegetation within a given area. Relevés also may be used to correlate changes in the floristic composition of plant communities with environmental gradients. In many ways, it represents a way of reordering, in a precise standardized form, the observations ecologists must make when surveying vegetation."

Following an initial reconnaissance of the area in a fixed-wing aircraft, several helicopter flights were made to examine suitable relevé sites over the full range of landscape features within the peatland complex, to collect representative samples of the peatland flora, and to collect representative water samples for chemical analysis.

2.2 Floristic studies

Vascular plants, mosses, and lichens have been collected at the relevé sites, which represent the major plant communities of the various landscape types. Additional sites have been examined in less representative communities, minor communities not subjected to relevé description, and in transitional communities, so that the floristic list for the site is reasonably complete. Voucher specimens have been prepared and are being deposited in the herbarium of the University of Minnesota. Particular attention has been given to the search for rare and endangered species.

Subsamples of bryophytes and lichens have been collected with disposable plastic gloves and will be archived for possible chemical analysis of trace elements in the future, should concerns about regional increases in air pollution justify such a study. Identifications by Professor Frank M. Bowers (bryophytes) and Professor Clifford H. Wetmore (lichens) are in progress.

2.3 Water chemistry

Water samples were taken over the full range of landscape features, in pint polyethylene bottles carefully washed in distilled water and rinsed by water from the site. Where standing water was not available, the bottles were filled by pressing them into the surface peat. At a few relatively dry sites, shallow pits were dug in the peat and allowed to fill with water.

The color of the water -- owing largely to dissolved organic matter, and an index of stagnation -- was measured as absorbance at 320 nanometers in a 1-cm cell with corex filter. Specific conductivity -- an index of total ionic concentration -- was measured with a platinum electrode. The conductivity data were standardized to 20°C, and the conductivity owing to hydrogen ions was subtracted in order to eliminate the effect of varying acidity (cf. Sjörs 1950). Acidity was measured as pH, using separate glass and calomel electrodes.

2.4 Stratigraphy

More than a dozen long peat cores have been taken by piston corer from representative sites within the peatland. Short cores (20 cm depth) have also been taken at several relevé sites. These long and short cores will be examined in order to obtain information on patterns of plant succession at various locations within the peatland.

3.0 RESULTS TO DATE

3.1 Plant communities

A series of 57 relevés, representing all the principal landforms of the peatland, was examined during 1978. The very extensive vegetation tables for these relevés are presently in manuscript, and will be typed early in the New Year.

3.2 Vascular plants

During the 1978 field season 590 vascular plants were collected and preserved. A list of species has been typed, along with an accompanying list of the legal and community descriptions for the collection sites, as given on the labels of the voucher specimens deposited in the herbarium of the University of Minnesota. These lists are given in Appendices 5.1 and 5.2.

3.3 Water samples

Chemical analyses (pH, specific conductivity, absorbance) have been performed on 78 water samples. The data tables are presently in manuscript, as further analyses are intended in 1979.

3.4 Peat cores

Fourteen long peat cores were taken down to the mineral soil, and a similar number of surface cores were taken to a depth of 20 cm. All are refrigerated at the University of Minnesota for future examination.

4.0 DISCUSSION AND PRELIMINARY CONCLUSIONS

4.1 Plant communities

The vegetation of the peatland was classified into six different plant communities based on floristic composition. This classification is based on the 57 relevés that were distributed over the major landforms of the study area. Water samples were collected from each relevé to determine the relationship between the vegetation and water chemistry. The plant communities of the Red Lake peatland may be separated into two distinct types based on species diversity and correlated with differences in water chemistry. The communities of the ombrotrophic bogs characteristic of the central and eastern portions of the peatland are distinguished by 1) low species diversity, 2) low (acidic) pH, and 3) poor supply of dissolved salts. These bog communities are isolated from mineral soil by thick layers of peat and receive most of their mineral supply from rainwater. In contrast, the communities of the minerotrophic water tracks are distinguished by 1) higher species diversity, 2) lower acidity (i.e., higher pH), and 3) richer supply of dissolved salts. These fen communities receive runoff from mineral soil of the adjacent uplands. However, the presence of minerotrophic fen water tracks in the center of the bog complex is puzzling because this area is surrounded by ombrotrophic bog vegetation.

Ombrotrophic Bogs

Two types of ombrotrophic bogs may be distinquished on the basis of floristic data. The *Carex oligosperma* - *Carex pauciflora* association occurs in non-forested openings whereas the *Carex trisperma* - *Vaccinium vitis-idaea* association is typically found under *Picea mariana* forests. These two associations are found on both the ovoid island bogs and the crested bog, and are not unique to any of the major landforms of the ombrotrophic bogs. A variant of the *Carex oligosperma* association contains certain species characteristic of minerotrophic water tracks and may represent a transition to the minerotrophic communities.

Carex oligosperma - *Carex pauciflora* association.

This association is distinquished by the presence of *Carex oligosperma* and *Carex pauciflora* and the absence of *Carex trisperma*. Also present are *Sarraceria purpurea*, *Kalmia polifolia*, *Andromeda glaucophylla*, *Eriophorum spissum*, *Chamaedaphne calyculata*, and *Ledum groenlandicum*. Clumps of *Picea mariana* are scattered throughout the stand but seldom reach heights of more than 15 to 20 feet (5 to 6 meters). The trees always show signs of layering and growth is slow.

The *Carex oligosperma* association occurs in non-forested openings such as the centers of the ovoid islands, the bog drains of the crested bog forest and a large fire scar southwest of Hillman Lake.

Habitat: The *Carex oligosperma* stands are sunny with a continuous mat of *Sphagnum* moss and tussocks of sedges. The substrate consists of hummocks and hollows but the surface is soft and subsidence occurs whenever weight is applied. The water table is close to the surface and pools of water appear with each footstep. Differences in elevation between the hummocks and hollows vary considerably but average about 40-50 centimeters.

Profile: The uppermost centimeters typically consist of unhumified *Sphagnum* peat interspersed with sedge shoots, rhizomes and rootlets. The water table is at or near the surface.

Water chemistry: This vegetation type is characterized by low (acidic) pH, high absorbance and low conductivity. The ranges of values are:

pH: 3.91 (bog drain) to 4.12 (ovoid island)

Conductivity: 17 (ovoid island) to 27 (bog drain) μmhos.

Absorbance: 1.12 (bog drain) to 1.31 (ovoid island)

Human impacts: The *Carex oligosperma* association does not seem to be affected by drainage ditches in the ovoid island area. Elsewhere the ditches may have lowered the water table of the large spruce islands and thus eliminated *Carex oligosperma* and *C. pauciflora*. An example of this process is found east of the ovoid islands on a spruce island with a conspicuous fire scar. The water table on this island is 40 cm below the surface of a hollow and no species of *Carex* are found in the non-forested clearings. Drainage ditches to the east, west, and south of this island have diverted most of the flow from the surrounding water track.

Carex trisperma - *Vaccinium vitis-idaea* association.

This association is distinguished by the presence of *Carex trisperma*, *Vaccinium vitis-idaea*, and *Smilacina trifolia*. Also present are most of the species found in the non-forested clearings except for *Carex oligosperma* and *Carex pauciflora*. The *Carex trisperma* association occurs in most forested areas of the ombrotrophic bogs. The most distinctive of these areas include the margins of the ovoid islands and the crested bog forest to the south. The forested stands typically contain stunted *Picea mariana* which is often infected by *Arceuthobium* pusillum (dwarf mistletoe). Larger trees are found along the outermost edges of the ovoid islands and within the interior of the crested bog forest. Occasional trees of Larix laricina are also present.

Habitat: The Carex trisperma - Vaccinium vitis-idaea association is at least partially shaded and has a continuous moss mat. The surface consists of hummocks and hollows with standing water occasionally present in the hollows. The driest hummocks are found at the bases of the trees. The stunted forests of the ovoid islands have occasional openings especially in heavy infection centers of Arceuthobium. The trees are usually conspicuously clumped as a result of layering. In contrast the interior of the crested bog forest has a relatively uniform canopy formed by the larger spruce trees.

Profile: The uppermost centimeters usually consist of partially humified moss and sedge peat with wood fragments and rootlets. The water table is at or near the surface.

Water chemistry: The water chemistry of this association is more variable than the non-forested communities except for pH. The need to dig pits in several stands to obtain water samples may account for part of this variability. The ranges of values are:

pH: 3.76 (crested bog forest) to 4.04 (ovoid island)

Conductivity: 12 (ovoid island) to 59 (crested bog forest) μmhos.

Absorbance: 0.99 (ovoid island) to 1.94 (crested bog forest).

Human impacts: The most noticeable impacts on this vegetation type are the result of lumbering and fire rather than drainage ditching. Large sections of the crested bog forest have been clear-cut as have been well-stocked spruce islands near the road. In addition most of the spruce islands near the Waskish Road (Highway 72) have been either burned or cut in the past 50 years.

The impact of ditching seems to be mostly confined to the immediate vicinity of the ditches in the ovoid island area. *Ledum groenlandicum* often predominates on the firmer, drier substrate of the spoil banks in forested areas. Elsewhere the ditches seem to have lowered the water table and produced spruce stands with better growth, for example in the area east and northeast of the ovoid islands.

Minerotrophic Water Tracks

The minerotrophic water tracks contain three distinct landforms: pools (troughs or flarks), hummocks (ridges or strings), and tear-drop shaped islands. A classification of the vegetation of these water tracks into plant communities does not exactly match these landforms. Only the pools and forested islands are distinguished floristically whereas the hummocks contain species common to the pools and the forest islands. The heterogeneity of the substrate of all three landforms in respect to water level accounts for a great deal of variability in the vegetation. The generally continuous intergradation of the minerotrophic vegetation types makes it impossible to describe their communities solely as discrete associations. Therefore the discussion of the minerotrophic vegetation will be organized according to the major landforms of the water tracks except where discrete associations are recognizable.

Pools (*Triglochin maritima* - *Drosera intermedia* association).

The dominant species of the pools are *Carex lasiocarpa* var. *americana*, *Carex livida* var. *grayana*, *Carex limosa*, *Menyanthes trifoliata* and *Rhynchospora alba*. However, most of these species also occur on hummocks or *Larix* islands and are not solely restricted to the large pools of the water tracks. Of much more restricted occurrence in the pools are *Triglochin maritima*, *Scheuchzeria palustris*, *Drosera intermedia* and *Utricularia intermedia*. These species are consistently present in the pool environment and define this type floristically even though they are not dominant components of the vegetation. Two conspicuous but minor associations within the pools are formed by clones of *Rhynchospora fusca* and *Carex exilis*. *Carex exilis* is usually associated with Scirpus cespitosus var. callosus. Together they may form well-developed hummocks or mosaics of hummocks and pools. Even the wettest pools have micro-relief that favors the establishment of typical hummock species such as Andromeda glaucophylla, Salix pedicellaris var. hypoglauca, Sarracenia purpurea and Thelypteris palustris var. pubescens. Although these species constitute a minor component of the pool vegetation their presence nevertheless helps to blur the distinction between pool and hummock.

Habitat: The pool communities are sunny and wind-swept with 6 - 20 centimeters of standing water. The deepest water levels are found in unditched portions of the western water track and also in the pristine area east of Highway 72. The latter area contains some pools that are over a man's head. In ditched portions of the water tracks water levels are much lower.

Even the wetter pools contain micro-hummocks that consist of flattened sedge shoots oriented approximately parallel to the direction of water movement. These shoots have the appearance of being worked by water, perhaps during spring break-up. The shoots are colonized by moss and hummock species and may constitute the origin of a hummock.

Profile: The uppermost centimeters from the substrate of the pools consist of compact unhumified sedge rhizomes and shoots interspersed with rootlets and humified organic matter.

Water chemistry: The water chemistry of the pools is variable and may be a reflection of disturbance produced by ditching.

pH: 4.54 (water track near ovoid islands) to 6.50 (near ovoid islands).

Conductivity: 33 (near ovoid islands) to 144 (pristine water track east of Hwy 72) µmhos.

Absorbance: 0.12 (near ovoid islands) to 1.02 (relatively dry water track near road).

Impact: The drainage ditches appear to have caused major changes in the pool communities. Water tracks are typically much drier on the downslope side of a ditch and a series of ditches may produce progressively drier conditions in a water track. Carex lasiocarpa is more tolerant of these conditions and becomes progressively more dominant in the pools. The aquatics such as Utricularia spp. and Menyanthes become much rarer as do the species of Drosera. Overall the species diversity of the pools declines with drier conditions.

Hummocks.

The hummocks are not characterized by a group of species that is restricted to this landform type. The dominant species of the hummocks occasionally occur on microhummocks in the pools but are more typical of Larix islands. These species include Andromeda glaucophylla, Vaccinium oxycoccus, Chamaedaphne calyculata, and Betula pumila var. glandulosa. Species typical of pools, especially Carex lasiocarpa var. americana, Menyanthes trifoliata and Carex livida var. grayana, are found along the edges of these hummocks or in water filled depressions within the hummock itself. The better developed hummocks typically contain small stunted trees of Larix laricina. Other species typical of hummocks include Sarracenia purpurea, Thelypteris palustris var. pubescens, Drosera rotundifolia and Salix pedicellaris var. hypoglauca.

Habitat: Hummocks vary considerably in size, shape, and height above the water level. In the driest water tracks hummocks are about 50-60 cm above the adjacent pools. In wetter situations the hummocks may be barely perceptible above the water surface. The substrate of a hummock is typically moss-covered except for wet water-filled depressions.

Profile: The uppermost centimeters of most hummocks contain partially humified sedge or moss peat with herbaceous fragments and rootlets.

Water chemistry: The water chemistry of hummocks is variable and the ranges of values are:

pH: 3.91 (string on edge of ovoid island) to 6.21 (near ovoid islands).

Conductivity: 20 (near ovoid islands) to 69 (near ovoid islands) µmhos.

Absorbance: 0.57 (near ovoid islands) to 1.26 (near ovoid islands).

Human impact: Hummocks are always best developed in drier water tracks that have been affected by drainage ditches. In ditched portions of the western water track the hummocks appear to be closer to each other and have anastomosed in places to form extensive brushlands with abundant dwarf birch *Betula pumila* var. *glandulifera*. Hummocks are also very conspicuous in water tracks between the ovoid islands and have been colonized by small *Larix* trees. In contrast hummocks are barely perceptible in the water tracks of the pristine area east of the road. These observations suggest that water levels and water flow exert a controlling influence on the development of hummocks. Ditching has created much drier conditions in many sections of the water tracks thus favoring the growth of hummocks.

Tear-drop Islands (*Carex paupercula* - *Calla palustris* association).

Within the western water track are tear-drop shaped islands that often have heads dominated by *Larix laricina* trees. Associated with *Larix* are trees of *Picea mariana* and more rarely *Thuja occidentalis*. The islands are variable in size and floristic composition and display the richest floristic composition of any landform in the peatland. Despite this variability the islands with well developed Larix-Picea stands have a distinctive assemblage of species that are generally restricted to this vegetation type. These species include Carex paupercula var. pallens, Carex canescens, Rumex orbiculatus, Aronia melanocarpa, Lonicera villosa var. solonis, Carex disperma, Carex pseudo-cyperus and Rubus pubescens. Many of the hummock species also occur on this vegetation type, for example Carex tenuiflora, Chamaedaphne calyculata, Betula pumila var. glandulifera, and Vaccinium oxycoccus.

This community type has a complex structure consisting of several discrete strata of trees, saplings, shrubs, and herbs. In addition a distinct assemblage of species is restricted to the water-filled pools within these islands. These species include: Calla palustris, Iris versicolor, Carex pseudo-cyperus and Typha latifolia.

Habitat: The canopy of Larix and Picea trees on these islands produces a partially shaded substrate that has a distinct hummock and hollow topography. The hollows often contain standing water but occasionally are drier. The hummocks seem to be composed of fallen trees that are covered with moss and sedges. Fallen or leaning trees are common within these stands.

Profile: The uppermost centimeters of the hummocks consist of partially humified moss and herbaceous peat with rootlets and wood fragments. Buried logs are common within the upper centimeters of peat.

Water chemistry: The values for the water chemistry of the _Larix-Picea_ islands are:

pH: 4.42 (_Larix_ stand on edge of water track) to 6.39 (western water track).

Conductivity: 31 (_Larix_ stand on edge of water track) to 75 (western water track) µmhos.

Absorbance: 0.26 (western water track) to 1.33 (_Larix_ stand on edge of water track).

Human impacts: Most of the larger _Larix-Picea_ islands occur in the unditched portions of the western water track and have not been influenced by human activity. However, several islands were sampled in ditched sections of the water track. These islands were drier with less standing water on the surface of the hollows. Several species were found only on these islands such as _Viburnum trilobum_, _Alnus rugosa_, and _Gymnocarpium dryopteris_, although their occurrence there may instead be related to the proximity of these islands to the edge of the peatland. Of all the minerotrophic vegetation types the _Larix-Picea_ islands display the least signs of human disturbance.

4.2 Vascular plants (with emphasis on rare and endangered species)

During the 1978 field season, 590 vascular plants were collected, identified, and preserved as voucher specimens from the study area. Out of this total collection, 198 taxa were found representing 104 genera in 50 plant families.

The collected plants represent all groups of vascular plants growing within the peatland proper. Also included are those plants growing in and alongside the margins of the drainage ditches within the peatland interior. However, plants growing in or near the large drainage ditch adjacent to Highway 72 were not included unless they were also found within the interior. Other areas not collected during the 1978 study include the peatland marginal communities, mineral soil upland sites (such as the Ludlow Lookout Tower Area), and roadside shoulders and embankments.

Of the plants collected, the Asteraceae with 8 genera and the Cyperaceae, Poaceae, and Orchidaceae with 7 genera represent the largest families. Eight genera have 4 or more taxa, and 4 of these, *Carex*, *Salix*, *Juncus*, and *Eriophorum* each have 7 or more taxa. The largest genus is *Carex* with 31 taxa. The 198 taxa are broken down into the major groups of vascular plants in the following tabulation:

Vascular Plant Group	TAXA Native	TAXA Introduced	TAXA Total	Genera	Families
Pteridophytes	7	0	7	6	3
Gymnosperms	4	0	4	4	2
Monocotyledons	83	0	83	32	12
Dicotyledons	102	2	104	62	33
TOTAL	196	2	198	104	50

TABLE 1

RARE AND ENDANGERED VASCULAR PLANT SPECIES
FOUND IN THE RED LAKE PEATLAND

CYPERACEAE

Carex exilis Dew.[c]
Cladium mariscoides (Muhl.) Torr.[a]
Rhynchospora fusca (L.) Ait. f.[a]

DROSERACEAE

Drosera anglica Huds.[c]
Drosera linearis Goldie.[a]

GENTIANACEAE

Gentiana rubricaulis Schwein.[a b]

JUNCACEAE

Juncus stygius L. var. *americanus* Buchenau.[a]

ORCHIDACEAE

Arethusa bulbosa L.[a b]
Cypripedium acaule Ait.[a b]
Habenaria lacera (Michx.) Lodd.[a b]
Liparis loeselii (L.) Rich.[a b]
Listera cordata (L.) R. Br.[a b]
Malaxis unifolia Michx.[a b]
Pogonia ophioglossoides (L.) Ker.[a b]
Pogonia ophioglossoides (L.) Ker. forma *albiflora* Rand & Redf.[a b]

XYRIDACEAE

Xyris montana Ries.[a]

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[a]Morley's (6) list of rare and endangered plants of Minnesota

[b]Minnesota Statute No. 17.23

[c]Plant taxonomists, University of Minnesota

The scientific name for each taxon is given in Appendix 5.1.

The sequence of plant families found in the table basically follows that of Ownbey (1) and within each family, the genera and species are alphabetically arranged. The scientific names follow Fernald (2) very closely but deviate in certain cases. When this occurs, the name used is based either upon the latest available monograph or that used in Gleason and Cronquist (3). The full authority names, which are abbreviated in the table, can be found in the first volume of Gleason (4). It should be noted that taxon rankings lower than that of form are not utilized.

Eight of the taxa found in the Red Lake peatland are very rare in Minnesota and represent significant westward extensions of range in the U.S.A., or even in North America. In addition, 100 new county records were obtained for the plants of Beltrami County, and 29 new records were obtained for Koochiching County.

An account of rare and endangered species recorded in the Red Lake peatland follows.

Rare or Endangered Vascular Plants in the Red Lake Peatland

During the 1978 field season, 16 vascular plants were found within the Red Lake peatland which are considered to be rare or endangered in Minnesota. As Table 1 shows, 9 of these are given limited legal protection under the Minnesota Wild Flower Conservation Law (5). Another 5 are included in Professor

Thomas Morley's (6) list of plants rare or endangered in Minnesota, but are not included in the Minnesota Wild Flower Conservation Law; and an additional 2 are plants which have only recently been discovered in the state.

During the 1978 study, 8 taxa of the Orchidaceae were found growing within the peatland. Although all members of this family are afforded limited legal protection under the Minnesota Wild Flower Conservation Law, the orchids growing within the study area vary greatly in frequency of occurrence and in specificity of habitat. *Arethusa bulbosa*, *Pogonia ophioglossoides*, and *Habenaria lacera* are commonly found within the peatland, but are confined to the minerotrophic fens. *Liparis loeselii* and *Malaxis unifolia* also colonize the fen areas, but are rare in occurrence. *Listera cordata* is confined to the ombrotrophic areas, where it grows in scattered colonies in forested bog. *Cypripedium acaule* is found both on the conifer islands and in the ombrotrophic bogs, but never in any great abundance. Significantly, *Pogonia ophioglossoides* forma *albiflora* was found growing at three minerotrophic fen localities within the Red Lake peatland. This is the first known record of this taxon from Minnesota.

Gentiana rubricaulis, also protected by the Minnesota Wild Flower Conservation Law, is of rather limited occurrence in the peatland, growing only sporadically in partially dried-up patterned fen.

As mentioned above, 5 vascular plants were found growing in the Red Lake peatland which are in Morley's list of plants rare or endangered in Minnesota, but are not included in the Minnesota Wild Flower Conservation Law. It is important to point out that although Morley's list has yet to be given legal significance, it includes those plants native to Minnesota that probably need protecting the most, owing to their pronounced scarcity within the state. His list is based on limited presence (fewer than 5 collection sites), as documented by preserved specimens at the University of Minnesota Herbarium, or on occurrence in only small geographical areas of Minnesota (6). The 5 vascular plants included in Morley's list are *Drosera linearis*, *Rhynchospora fusca*, *Xyris montana*, *Juncus stygius* var. *americanus*, and *Cladium mariscoides*.

Drosera linearis is locally abundant in the pools of the great western water track but thus far unknown from the central and eastern portions of the peatland. The Red Lake peatland represents the third known station of this species from Minnesota. In Canada, this primarily eastern species ranges from Newfoundland to as far west as Alberta (7), but presently the Red Lake fen represents the western-most station of this plant in the United States.

Rhynchospora fusca is locally abundant on the edge of fen pools and in the flarks of the patterned fens throughout the peatland area. The peatland represents the second known station for this species in Minnesota. Based on the distribution given by present-day manuals, this peatland represents the westernmost station for this plant in the United States and only one isolated station on the Saskatchewan River near the Saskatchewan-Manitoba boundary (8) represents a more western locality in North America.

During the 1978 study, _Xyris montana_ was found growing on the edge of fen pools at two localities within the peatland area. At one of these sites the species was especially abundant (Koochiching County - SW¼NW¼ Sec. 16 T156N R29W). The Red Lake peatland is the third known station for this plant in Minnesota. According to Scoggan (7) and Fernald (2), _X. montana_ is a plant primarily of eastern Canada that has only limited local extensions into the United States, with these rarely found west of Michigan.

Juncus stygius var. _americanus_ was found growing on the edge of fen pools at three localities within the peatland area. The Red Lake peatland is the third known station for this species in Minnesota. Scoggan (7) gives this boreal plant as ranging in North America from Alaska to northern Saskatchewan then eastward to Newfoundland with several local extensions into the United States. At present, the Red Lake peatland represents the westernmost station of this plant in the contiguous United States.

Cladium mariscoides is scattered throughout the wettest portions of most, if not all, of the patterned fens, but is found most frequently in the great western patterned water track. This is the fifth known station for this species in Minnesota. The Red Lake peatland represents the westernmost station for this plant in the United States and only one isolated station near Dahlton, Saskatchewan (7) represents a more western locality in North America.

Drosera anglica and *Carex exilis*, although not included in either Morley's list or the Minnesota Wild Flower Conservation Law, are Minnesota rarities that were found within the study area. Both of these plants have only recently been found growing in the state.

Drosera anglica is locally abundant in the flarks of the patterned water tracks throughout the peatland area. Although Hofstetter (9) reported this plant to be growing in the Red Lake peatland, there were no specimens of *D. anglica* from Minnesota present in the University Herbarium prior to 1978. Thus, voucher specimens of *D. anglica* taken during the 1978 study represent the first verified account of this plant's presence in Minnesota. According to Hultén (10), this is a circumboreal species which has several local extensions into the United States. The Red Lake peatland can be considered an additional such extension.

Carex exilis is locally abundant throughout the peatland area on the poor fen ecotones (laggs) which separate the ombrotrophic ovoid islands and the mineral-rich water tracks. It also sometimes is a constituent of the ridge portion of the patterned fen. Although collected from the peatland area prior to 1978, it is important to note that *C. exilis* is unknown from elsewhere in Minnesota. According to Scoggan (7) and Fernald (2), this species is known primarily from eastern Canada and northeastern United States and has only limited local populations extending west of Michigan. At present, the Red Lake peatland represents the westernmost known station of this species in the United States and Canada.

4.3 Water chemistry

The bog and fen waters are distinctly different only in their acidity. True bog waters exhibit pH values below 4.6 (median 4.0) and true fen waters exhibit pH values above 5.0 (median 6.0). However, a few strongly acid waters are recorded from generally minerotrophic water tracks, and occur at marginal sites where the water is relatively stagnant and bog vegetation is colonizing the fen.

There is considerable overlap in the corrected conductivity values, although the median for the fen (51 μmho) is about twice that for the bog (25 μmho). The highest conductivities indicate the most strongly minerotrophic fen sites, which also exhibit the lowest acidities. Specific conductivity rises from 30 μmho at pH 5.5 to 130 μmho at pH 7.0.

The bog waters, which are relatively stagnant as compared with most fen waters, are all highly colored with absorbance values of 0.9-2.2 (median 1.3). Some fen waters are also stagnant and highly colored, with absorbance values up to 2.0. However, most are much less colored (median absorbance 0.5), and some are very clear with absorbance values as low as 0.1. These are presumably the waters with the most rapid flow, which do not accumulate large amounts of dissolved organic matter.

A notable feature of the present results is that the water tracks within the main bog complex of crested bogs, ovoid spruce islands, and *Carex oligosperma* meadows are clearly minerotrophic, above pH 5.0 and bearing a vegetation with numerous fen indicator species. It may also be remarked that flocculent ferric hydroxide is characteristically present in abundance in the water tracks, and can only have come from adjacent or subjacent mineral soils. There is no evidence as yet for any source of artesian water within the bog complex, nor do the vegetation patterns suggest any likely directions for the inflow of surface minerotrophic waters. It is possible that these come only during periods of high water, for example during spring thaw. Investigation of water flow at such times ought therefore to be given high priority in future investigations.

4.4 Stratigraphy

Stratigraphic investigations have not as yet progressed very far. Peat depths range from about 1.5 to 4 m at the 17 sites probed for this purpose. Within the main bog complex depths are generally greater than 3 m. The shallowest peats are found in the upstream (western) part of the main western water track.

REFERENCES

(1) Ownbey, Gerald B. 1969. Annotated checklist of the Seed Plants, Ferns and Fern Allies for Clearwater County and Itasca State Park, Minnesota. Dept. of Botany, University of Minnesota, Minneapolis.

(2) Fernald, M. L. 1970. Gray's Manual of Botany. 8th ed., corrected printing. D. Van Nostrand Co., New York.

(3) Gleason, Henry A., and Cronquist, Arthur. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Van Nostrand Reinhold Co., New York.

(4) Gleason, Henry A. 1952. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. Vol. I. The New York Botanical Garden, New York.

(5) Minnesota Statute. No. 17.23.

(6) Morley, Thomas. 1972. Rare or Endangered Plants of Minnesota. Unpublished.

(7) Scoggan, H. J. 1978. The Flora of Canada. National Museums of Canada, Ottawa.

(8) Hultén, E. 1958. The Amphi-Atlantic Plants and Their Phytogeographical Connections. Almquist and Wiksell, Stockholm, Sweden.

(9) Hofstetter, R. H. 1969. Floristic and Ecological Studies of Wetlands in Minnesota. Ph.D. Thesis, University of Minnesota.

(10) Hultén, E. 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, California.

5.0 APPENDICES

5.1 Vascular plants collected in the Red Lake peatland

Ferns and Fern Allies

EQUISETACEAE

Equisetum fluviatile L.

OSMUNDACEAE

Osmunda cinnamomea L.

POLYPODIACEAE

Athyrium filix-femina (L.) Roth. var. *michauxii* (Spreng.) Farwell.
Dryopteris cristata (L.) Gray.
Dryopteris spinulosa (Mueller) Watt.
Gymnocarpium dryopteris (L.) Newm.
Thelypteris palustris Schott var. *pubescens* (Lawson) Fern.

Gymnosperms

CUPRESSACEAE

Thuja occidentalis L.

PINACEAE

Larix laricina (Du Roi) K. Koch.
Picea mariana (Mill.) BSP.
Pinus banksiana Lamb.

Angiosperms (Monocots and Dicots)

APIACEAE

Cicuta bulbifera L.
Sium suave Walt.

APOCYNACEAE

Apocynum cannabinum L.

VASCULAR PLANTS (cont.)

ARACEAE

Calla palustris L.

ASCLEPIADACEAE

Asclepias incarnata L.

ASTERACEAE

Aster junciformis Rydb.
Aster puniceus L.
Aster umbellatus Mill. var. pubens Gray.
Bidens cernua L.
Bidens connata Muhl. var. petiolata (Nutt.) Farw.
Cirsium arvense (L.) Scop.
Cirsium muticum Michx.
Eupatorium maculatum L.
Eupatorium perfoliatum L.
Petasites sagittatus (Pursh) Gray.
Senecio pauperculus Michx.
Solidago canadensis L.
Solidago graminifolia (L.) Salisb.
Solidago uliginosa Nutt.
Sonchus arvensis L. var. glabrescens Guenth., Grab. and Wimm.

BETULACEAE

Alnus rugosa (Du Roi) Spreng.
Betula papyrifera Marsh.
Betula pumila L. var. glandulifera Regel.
Betula X sandbergi Britt.

CAMPANULACEAE

Campanula aparinoides Pursh.

CAPRIFOLIACEAE

Lonicera oblongifolia (Goldie) Hook.
Lonicera villosa (Michx.) R. & S. var. solonis (Eaton) Fern.
Viburnum trilobum Marsh.

CARYOPHYLLACEAE

Stellaria longifolia Muhl.

CORNACEAE

Cornus canadensis L.
Cornus rugosa Lam.
Cornus stolonifera Michx.

CYPERACEAE

Carex angustior Mackenz.
Carex aquatilis Wahlenb. var. *altior* (Rydb.) Fern.
Carex aurea Nutt.
Carex bebbii Olney.
Carex brunnescens (Pers.) Poir. var. *sphaerostachya* (Tuckerm.) Kukenth.
Carex buxbaumii Wahlenb.
Carex canescens L.
Carex cephalantha (Bailey) Bickn.
Carex chordorrhiza L. f.
Carex diandra Schrank.
Carex disperma Dew.
Carex exilis Dew.
Carex interior Bailey.
Carex lacustris Willd.
Carex lanuginosa Michx.
Carex lasiocarpa Ehrh. var. *americana* Fern.
Carex leptalea Wahlenb.
Carex limosa L.
Carex livida (Wahlenb.) Willd. var. *grayana* (Dewey) Fern.
Carex oligosperma Michx.
Carex pauciflora Lightf.
Carex paupercula Michx. var. *pallens* Fern.
Carex projecta Mackenz.
Carex pseudo-cyperus L.
Carex rostrata Stokes var. *utriculata* (Boott) Bailey.
Carex stricta Lam.
Carex tenera Dew.

CYPERACEAE (cont.)

Carex tenuiflora Wahlenb.
Carex trisperma Dew.
Carex vaginata Tausch.
Carex viridula Michx.
Cladium mariscoides (Muhl.) Torr.
Dulichium arundinaceum (L.) Britton.
Eleocharis compressa Sulliv.
Eriophorum angustifolium Honckeny.
Eriophorum chamissonis C. A. Meyer.
Eriophorum gracile Koch.
Eriophorum spissum Fern.
Eriophorum tenellum Nutt.
Eriophorum virginicum L.
Eriophorum viridi-carinatum (Engelm.) Fern.
Rhynchospora alba (L.) Vahl.
Rhynchospora fusca (L.) Ait. f.
Scirpus atrocinctus Fern.
Scirpus cespitosus L. var. *callosus* Bigel.
Scirpus hudsonianus (Michx.) Fern.
Scirpus validus Vahl.

DROSERACEAE

Drosera anglica Huds.
Drosera intermedia Hayne.
Drosera linearis Goldie.
Drosera rotundifolia L.

ERICACEAE

Andromeda glaucophylla Link.
Chamaedaphne calyculata (L.) Moench.
Gaultheria hispidula (L.) Bigel.
Kalmia polifolia Wang.
Ledum groenlandicum Oeder.
Vaccinium angustifolium Ait.
Vaccinium myrtilloides Michx.

ERICACEAE (cont.)

Vaccinium oxycoccos L.
Vaccinium vitis-idaea L. var. *minus* Lodd.

GENTIANACEAE

Gentiana rubricaulis Schwein.
Menyanthes trifoliata L. var. *minor* Raf.

HIPPURIDACEAE

Hippuris vulgaris L.

HYPERICACEAE

Hypericum virginicum L. var. *fraseri* (Spach) Fern.

IRIDACEAE

Iris versicolor L.

JUNCACEAE

Juncus alpinus Vill. var. *rariflorus* Hartm.
Juncus brevicaudatus (Engelm.) Fern.
Juncus canadensis J. Gay.
Juncus dudleyi Wieg.
Juncus nodosus L.
Juncus pelocarpus Mey.
Juncus stygius L. var. *americanus* Buchenau.

JUNCAGINACEAE

Scheuchzeria palustris L. var. *americana* Fern.
Triglochin maritima L.

LAMIACEAE

Lycopus americanus Muhl.
Lycopus uniflorus Michx.
Scutellaria epilobiifolia Hamilt.

LENTIBULARIACEAE

Utricularia cornuta Michx.

LENTIBULARIACEAE (cont.)

Utricularia intermedia Hayne.
Utricularia minor L.
Utricularia vulgaris L.

LILIACEAE

Maianthemum canadense Desf.
Smilacina trifolia (L.) Desf.

LOBELIACEAE

Lobelia kalmii L.

LORANTHACEAE

Arceuthobium pusillum Peck.

MYRICACEAE

Myrica gale L.

NYMPHAEACEAE

Nuphar variegatum Engelm.

ONAGRACEAE

Epilobium angustifolium L.
Epilobium leptophyllum Raf.
Epilobium palustre L.

ORCHIDACEAE

Arethusa bulbosa L.
Cypripedium acaule Ait.
Habenaria lacera (Michx.) Lodd.
Liparis loeselii (L.) Rich.
Listera cordata (L.) R. Br.
Malaxis unifolia Michx.
Pogonia ophioglossoides (L.) Ker.
Pogonia ophioglossoides (L.) Ker. forma *albiflora* Rand & Redfield.

POACEAE

Agrostis scabra Willd.
Bromus ciliatus L.
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis inexpansa Gray var. *brevior* (Vasey) Stebbins.
Calamagrostis neglecta (Ehrh.) Gaertn.
Cinna latifolia (Trin.) Griseb.
Glyceria borealis (Nash) Batchelder.
Glyceria striata (Lam.) Hitchc.
Muhlenbergia glomerata (Willd.) Trin.
Phragmites communis Trin. var. *berlandieri* (Fourn.) Fern.

POLYGONACEAE

Polygonum sagittatum L.
Rumex orbiculatus Gray.

PRIMULACEAE

Lysimachia terrestris (L.) BSP.
Lysimachia thyrsiflora L.
Trientalis borealis Raf.

PYROLACEAE

Monotropa uniflora L.
Pyrola asarifolia Michx. var. *purpurea* (Bunge) Fern.
Pyrola secunda L. var. *obtusata* Turcz.

RANUNCULACEAE

Caltha palustris L.
Ranunculus gmelini DC. var. *hookeri* (D. Don) Benson.

RHAMNACEAE

Rhamnus alnifolia L'Her.

ROSACEAE

Amelanchier humilis Wieg. var. *compacta* Niels.
Aronia melanocarpa (Michx.) Spach.

ROSACEAE (cont.)

<u>Geum</u> <u>aleppicum</u> Jacq. var. <u>strictum</u> (Ait.) Fern.
<u>Potentilla</u> <u>fruticosa</u> L.
<u>Potentilla</u> <u>palustris</u> (L.) Scop.
<u>Rubus</u> <u>acaulis</u> Michx.
<u>Rubus</u> <u>pubescens</u> Raf.
<u>Rubus</u> <u>strigosus</u> Michx.
<u>Spiraea</u> <u>alba</u> Du Roi.

RUBIACEAE

<u>Galium</u> <u>labradoricum</u> Wieg.

SALICACEAE

<u>Populus</u> <u>balsamifera</u> L.
<u>Populus</u> <u>tremuloides</u> Michx.
<u>Salix</u> <u>bebbiana</u> Sarg.
<u>Salix</u> <u>candida</u> Fluegge.
<u>Salix</u> <u>discolor</u> Muhl.
<u>Salix</u> <u>gracilis</u> Anderss.
<u>Salix</u> <u>interior</u> Rowles.
<u>Salix</u> <u>lucida</u> Muhl.
<u>Salix</u> <u>pedicellaris</u> Pursh var. <u>hypoglauca</u> Fern.
<u>Salix</u> <u>planifolia</u> Pursh.
<u>Salix</u> <u>pyrifolia</u> Anderss.
<u>Salix</u> <u>serissima</u> (Bailey) Fern.

SARRACENIACEAE

<u>Sarracenia</u> <u>purpurea</u> L.

SAXIFRAGACEAE

<u>Parnassia</u> <u>glauca</u> Raf.
<u>Parnassia</u> <u>palustris</u> L. var. <u>neogaea</u> Fern.

SCROPHULARIACEAE

<u>Gerardia</u> <u>paupercula</u> (Gray) Britt. var. <u>borealis</u> (Pennell) Deam.

SCROPHULARIACEAE (cont.)

Mimulus ringens L.
Pedicularis lanceolata Michx.

SPARGANIACEAE

Sparganium minimum (Hartm.) Fries.

TYPHACEAE

Typha latifolia L.

VIOLACEAE

Viola incognita Brain.
Viola mackloskeyi Lloyd ssp. *pallens* (Banks) Baker.
Viola nephrophylla Greene.

XYRIDACEAE

Xyris montana Ries.

ZOSTERACEAE

Potamogeton natans L.
Potamogeton gramineus L.

5.2 Vascular plant collection sites

Coll. Site No.	Legal Description	Community Description
	Beltrami County	
1.	NE¼NW¼ Sec.1 T156N R31W	Partially Dried-up Patterned Fen
2.	NW¼NE¼ Sec.1 T156N R31W	Edge of Drainage Ditch
3.	NW¼NW¼ Sec.19 T156N R30W	Black Spruce Bog
4.	SW¼NW¼ Sec.19 T156N R30W	String of Patterned Fen
5.	SW¼NW¼ Sec.19 T156N R30W	Flark of Patterned Fen
6.	SW¼NW¼ Sec.19 T156N R30W	Edge of Drainage Ditch
7.	SW¼SE¼ Sec.1 T156N R31W	Black Spruce Bog
8.	SW¼SE¼ Sec.1 T156N R31W	Drainage Ditch
9.	SW¼NW¼ Sec.14 T156N R31W	String of Patterned Fen
10.	SW¼NW¼ Sec.14 T156N R31W	Flark of Patterned Fen
11.	NE¼SE¼ Sec.13 T156N R31W	Partially Dried-up Patterned Fen
12.	NE¼SE¼ Sec.13 T156N R31W	Edge of Drainage Ditch
13.	S½SE¼ Sec.32 T156N R32W	Edge of Hilman Lake
14.	S½SE¼ Sec.32 T156N R32W	Open Bog
15.	NE¼NE¼ Sec.17 T156N R31W	Poor Fen Ecotone (Lagg)
16.	NE¼NE¼ Sec.17 T156N R31W	Edge of Black Spruce Bog
17.	NE¼NE¼ Sec.17 T156N R31W	Edge of Drainage Ditch
18.	NE¼SE¼ Sec.17 T156N R31W	Conifer Island
19.	SW¼NW¼ Sec.36 T156N R32W	Conifer Island
20.	SW¼NW¼ Sec.36 T156N R32W	Poor Fen Ecotone (Lagg)
21.	SW¼NW¼ Sec.36 T156N R32W	String of Patterned Fen
22.	SW¼NW¼ Sec.36 T156N R32W	Flark of Patterned Fen
23.	NE¼SW¼ Sec.25 T156N R32W	String of Patterned Fen
24.	NE¼SW¼ Sec.25 T156N R32W	Flark of Patterned Fen
25.	NE¼NW¼ Sec.25 T156N R32W	String of Patterned Fen
26.	NE¼NW¼ Sec.25 T156N R32W	Flark of Patterned Fen
27.	NE¼NW¼ Sec.25 T156N R32W	Black Spruce Bog
28.	NE¼NW¼ Sec.25 T156N R32W	Edge of Drainage Ditch
29.	SW¼NE¼ Sec.24 T156N R32W	Poor Fen Ecotone (Lagg)
30.	SW¼NE¼ Sec.24 T156N R32W	Edge of Fen Pool

COLLECTION SITES (cont.)

31.	NW¼SE¼	Sec.25	T156N	R32W	Open Bog
32.	NE¼NW¼	Sec.8	T156N	R31W	Poor Fen Ecotone (Lagg)
33.	NE¼NW¼	Sec.8	T156N	R31W	Conifer Island
34.	NW¼NW¼	Sec.28	T156N	R31W	Open Bog
35.	SE¼NE¼	Sec.1	T156N	R31W	Partially Dried-up Patterned Fen
36.	NW¼SW¼	Sec.7	T156N	R30W	String of Patterned Fen
37.	NW¼SW¼	Sec.7	T156N	R30W	Flark of Patterned Fen
38.	NW¼SW¼	Sec.7	T156N	R30W	Edge of Drainage Ditch
39.	NW¼SW¼	Sec.7	T156N	R30W	Drainage Ditch
40.	SW¼SE¼	Sec.12	T155N	R32W	Open Bog
41.	SW¼SE¼	Sec.12	T155N	R32W	Black Spruce Bog
42.	E½	Sec.13	T155N	R32W	Open Bog
43.	E½	Sec.13	T155N	R32W	Edge of Drainage Ditch
44.	E½	Sec.13	T155N	R32W	Drainage Ditch
45.	SW¼NW¼	Sec.18	T156N	R30W	String of Patterned Fen
46.	SW¼NW¼	Sec.18	T156N	R30W	Flark of Patterned Fen
47.	SW¼NW¼	Sec.18	T156N	R30W	Edge of Drainage Ditch
48.	N½SW¼	Sec.18	T156N	R30W	String of Patterned Fen
49.	N½SW¼	Sec.18	T156N	R30W	Flark of Patterned Fen
50.	NE¼SW¼	Sec.18	T156N	R30W	Edge of Drainage Ditch
51.	N½	Sec.10	T155N	R33W	String of Patterned
52.	N½	Sec.10	T155N	R33W	Flark of Patterned Fen
53.	NE¼NW¼	Sec.5	T155N	R33W	Flark of Patterned Fen
54.	NE¼NW¼	Sec.5	T155N	R33W	Conifer Island
55.	NW¼SE¼	Sec.32	T156N	R33W	Conifer Island
56.	SW¼NE¼	Sec.32	T156N	R33W	String of Patterned Fen
57.	SW¼NE¼	Sec.32	T156N	R33W	Flark of Patterned Fen
58.	SE¼SE¼	Sec.3	T155N	R33W	Conifer Island
59.	SE¼NW¼	Sec.5	T155N	R33W	String of Patterned Fen
60.	SE¼NW¼	Sec.5	T155N	R33W	Flark of Patterned Fen
61.	NW¼NE¼	Sec.15	T156N	R32W	Flark of Patterned Fen
62.	NE¼SE¼	Sec.10	T156N	R32W	Conifer Island
63.	SW¼SE¼	Sec.10	T156N	R32W	String of Patterned Fen
64.	NW¼SE¼	Sec.15	T156N	R32W	Flark of Patterned Fen
65.	NW¼SE¼	Sec.15	T156N	R32W	String of Patterned Fen

66.	SW¼SE¼	Sec.15	T156N	R32W	Black Spruce Bog
67.	SE¼NW¼	Sec.15	T156N	R32W	Conifer Island
68.	SW¼SW¼	Sec.15	T156N	R32W	String of Patterned Fen
69.	SW¼SW¼	Sec.15	T156N	R32W	Flark of Patterned Fen
70.	SW¼SW¼	Sec.15	T156N	R32W	Edge of Drainage Ditch
71.	NW¼NE¼	Sec.10	T156N	R32W	Conifer Island
72.	NW¼NE¼	Sec.10	T156N	R32W	Edge of Drainage Ditch
73.	SW¼NE¼	Sec.10	T156N	R32W	String of Patterned Fen
74.	SE¼SW¼	Sec.3	T156N	R32W	Edge of Drainage Ditch
75.	SW¼NE¼	Sec.4	T155N	R34W	Flark of Patterned Fen
76.	NW¼NW¼	Sec.24	T156N	R32W	Flark of Patterned Fen
77.	NE¼NW¼	Sec.1	T156N	R31W	Edge of Seepage Drain
78.	NW¼SW¼	Sec.8	T156N	R31W	Conifer Island

Koochiching County

79.	NW¼NW¼	Sec.21	T156N	R29W	Flark of Patterned Fen
80.	SW¼NW¼	Sec.16	T156N	R29W	Poor Fen Ecotone (Lagg)
81.	SW¼NW¼	Sec.16	T156N	R29W	Flark of Patterned Fen
82.	SW¼NW¼	Sec.16	T156N	R29W	Edge of Fen Pool
83.	SW¼NW¼	Sec.16	T156N	R29W	Fen Pool
84.	NW¼NW¼	Sec.16	T156N	R29W	Edge of Fen Pool
85.	NW¼NW¼	Sec.16	T156N	R29W	Fen Pool
86.	NW¼NW¼	Sec.16	T156N	R29W	String of Patterned Fen
87.	NW¼NW¼	Sec.16	T156N	R29W	Flark of Patterned Fen
88.	SW¼NW¼	Sec.32	T156N	R29W	Bog Drain
89.	SW¼NE¼	Sec.15	T156N	R29W	Flark of Patterned Fen

6.0 RECOMMENDATIONS FOR ADDITIONAL RESEARCH 1979-1981

6.1 The effects of drainage ditches on vegetation patterns.

The spoil banks of many drainage ditches slow or even halt the water flow across the peatland. The results are seen particularly where a ditch crosses a water track, where the natural water flow tends to be concentrated. On the upslope side of the ditch the water may accumulate and partially flood the pattern of transverse ridges and pools (the ribbed fen) that characterizes most water tracks. On the downslope side of the ditch the water track is partially dried out, and shrubs invade the ridges. The contrast along many ditches is visible on air photographs. The relations are particularly noticeable on opposite sides of the Waskish-Baudette road (Highway 72). The ditch on the east side of the road is commonly full of flowing water after rains, whereas that on the west has little water. Where desiccation on the west side is moderate, the ribbed pattern of the water track may become accentuated by shrubs invading the ridges. Where desiccation is more severe, it has converted some of the fen to an unpatterned area of dwarf birch shrubland, and other patterns and vegetation communities have been disrupted. The degree of modification should be measured by making systematic vegetation plots in the modified areas, by investigating the water level and water content in the peat, and by analyzing water samples to see if water chemistry has been affected by the changes in water flow. In some cases the spoil banks carry a vegetation of willow shrubs and other hardwoods, implying that mineral soil has been dredged from the ditches; nutrients from such mineral-soil sources may change the chemistry of the water flowing in the ditch or seeping across the peatland. Systematic water samples should be taken to examine this question.

6.2 <u>The peatland complex northeast of Highway 72</u>.

The complex of raised bogs, water tracks, and ovoid islands northeast of Highway 72 is completely unditched and thus essentially pristine in its vegetational development and its water chemistry. More extensive floristic, vegetational, and hydrochemical study of this area should be undertaken, for comparison with the largely ditched area studied in 1978 west of the highway. A preliminary survey in this area indicates a greater floristic richness here, and a close search should be made for rare and endangered species. The vegetation patterns are certainly well developed here and are somewhat less complex than those west of the highway, perhaps because they are less altered by disturbance. This may be the area most suitable for the highest level of protection from disturbance.

6.3 <u>Vegetational and floristic studies of wetland border communities</u>.

Vegetational and floristic studies, in conjunction with analysis of water chemistry, should be made of representative samples of transitional wetland communities bordering the peatland complexes. A proper analysis is possible now that the major peatland communities have been established, and it is of great importance because the marginal areas may be those parts of the peatland complex most used by wildlife of interest to man (e.g., moose, deer, wildfowl, etc.). There appear to be large areas of willow scrub that may be of particular importance in this connection.

6.4 Vegetational analysis of large peatlands in St. Louis and Lake Counties.

Vegetational analysis (by the relevé method) and floristic study of the large peatlands in St. Louis and Lake Counties is required, for comparison with those of the Red Lake area. Preliminary studies suggest that the peatlands of northeastern Minnesota do not exhibit the diversity of pattern evident in northwestern Minnesota. Their floristic diversity may also be less, because the nutrient inputs to the bogs from the non-calcareous glacial drift of the area are likely to be low; but on the other hand it is possible that more northerly elements of the bog flora may be present in northeastern Minnesota because of the cooler, wetter climate.

6.5 Stratigraphic studies.

Stratigraphic study of peat cores should be undertaken, to determine how the peatland patterns have become established, and whether they had reached a relatively stable state prior to ditching or other disturbance. Understanding of the mechanism of pattern formation will be of great value in working out how and why patterns have changed in response to ditching and road-building, and how they may be preserved in relatively pristine areas around which peat mining may occur. Analysis of interstitial water at different depths in the peat, and in the underlying mineral soil, may provide clues to the sources of water flowing in various parts of the peatland. The source of minerotrophic water in the water tracks within the major *Sphagnum* bog complexes is of particular interest in this connection. The stratigraphic studies in certain areas should include analysis of interstitial water to determine whether some of the water moves upward under artesian pressure, thus possibly explaining unexpectedly high values of pH discovered in the heart of the complex of raised bogs. If the interstitial water has a high ionic content and high humic color compared to the surface water, then presumably it has been in contact with the decomposing peat for a long time, whereas if its chemical makeup is similar to that of the surface water then it may be moving rapidly through the peat under artesian pressure.

6.6 Analysis of the role of fire in ovoid bog islands.

Analysis of the role of fire in the large, ovoid bog islands of *Sphagnum* moss and black spruce will be useful in attempting to understand why these islands have poor spruce growth in the center, and locally in some marginal areas. Recent fire scars are evident in some areas, and so also are patches of mistletoe infestation. It is uncertain whether these open areas are a natural consequence of increased wetness in the island centers or a response to fire or other factors. (We do not even know whether the present tree cover on the ovoid islands is greater or less than in the past.) Comparison of the ditched and unditched areas will be of especial interest in this connection, as will further comparisons of the vegetation and water chemistry of the island centers with the centers of the crested raised bogs that have radiating lines of clumped spruce.

6.7 Further studies of water and peat chemistry.

Further study of surface water chemistry and peat chemistry, together with analysis of microtopographic gradients, is required in order to understand the pattern of water flow and the balance between the ions supplied directly by rainwater and those carried by water that has percolated through adjacent or subjacent mineral soil or decomposing peat. This balance is of the greatest significance in determining whether fen or bog vegetation will be present, and the lines of water flow from the mineral soil clearly play a major role in determining vegetation patterns. The degree of slope in the water tracks will also be of importance in determining the frequency and distinctness of "ribs" in the "ribbed fen", with its ridges (or ribs) and troughs oriented across the line of water flow. Degree of slope may also be of importance in analyzing the effects of ditching and road-building, as will studies of water and peat chemistry.

6.8 Investigation of the rates of peat accumulation.

Rates of peat accretion in various parts of the patterned wetland should be investigated so that we may gain some idea of the rates of regrowth to be expected in areas that might be mined. Such knowledge could well assist plans for reclamation of exploited areas, if we can establish under what hydrologic regimes and vegetation types peat accumulates rapidly, and where it accumulates slowly. At present we are uncertain as to whether peat is actually still accumulating in the unditched areas, or has risen to some climatically determined limit. Likewise we do not know what the response has been to ditching and roadbuilding, although we do know that vegetation patterns have been markedly affected. For dating various levels of peat, the carbon-14 technique can be employed. The marked rise in ragweed pollen following European settlement can be used to indicate the advent and subsequent influence of modern man upon the peatland.

SECTION I

REMOTE SENSING APPLICATIONS IN AGRICULTURE AND FORESTRY

IAFHE RSL Project G-78-79(3) December 11, 1978

VEGETATION ANALYSIS OF SELECTED BELTRAMI, KOOCHICHING AND ST. LOUIS COUNTY PEATLANDS BY REMOTE SENSING METHODS

by

R. Hagen and M. Meyer

Univ. of Minn. College of Forestry

A Progress Report to the Minnesota DNR Minerals Division - Peat Program for the period October 1 - December 15, 1978

A REPORT OF RESEARCH
by the
Remote Sensing Laboratory
of the
College of Forestry and the Agricultural Experiment Station
Institute of Agriculture, Forestry and Home Economics
University of Minnesota
St. Paul, Minnesota

VEGETATION ANALYSIS OF SELECTED BELTRAMI, KOOCHICHING AND ST. LOUIS COUNTY PEATLANDS BY REMOTE SENSING METHODS

by

M. Meyer and R. Hagen

1.0 Introduction

The present one-year study is divided into two phases, each with the following objectives:

Phase I - Preparation of 100% site-specific vegetation cover type maps of portions of 9 $7\frac{1}{2}$-minute USGS quadrangles in the Upper Red Lake Bog and portions of 6 $7\frac{1}{2}$-minute quadrangles in St. Louis County (circa 315 square miles total). Classification to be accomplished from the most recent existing 1:15,840 summer B&W infrared aerial photography.

Phase II - A two-camera 35mm aerial photography camera system will provide color infrared coverage of up to 35 miles of representative transects selected by the investigators. Continuous coverage of the transects will be flown at circa 1:84,000 and photo plots at circa 1:12,000 will be flown at selected intervals along the transects.

2.0 Methods

2.1 Phase I

2.11 Interpretation of the 1:15,840 scale photography is being done while viewing the photographs in stereo using a reflecting mirror stereoscope.

2.12 Interpretation is being done on clear, stable-base overlays registered to alternate photographs.

2.13 Minimum size of typing unit is $7\frac{1}{2}$ acres.

2.14 The classification scheme has been developed by the investigators under guidelines set down by the DNR Peat Program.

2.15 Necessary field checking has been done largely by helicopter for the Red Lake Peatland and by bog tractor and foot for the two Toivola bogs.

2.16 To aid the photo interpreter, a considerable number of low altitude, aerial high oblique color slides were taken of the study area from the helicopter or from fixed-wing aircraft. The location and approximate field of view of the oblique photographs were then indexed on 7½-minute orthophotoquads.

2.17 A carousel slide projector and screen are set up in conjunction with the photo interpreter's working station such that the interpreter can alternate between the stereo image of an area and the projected image of the corresponding oblique or color infrared transparency simply by turning in his chair.

2.18 The interpreted detail on the 9x9-inch overlays will be transferred to overlays registered to 1:24,000 scale orthophotoquads using an overhead projector.

2.19 Area measurements by cover type and by quadrangle will be made using an electronic planimeter.

2.20 A final copy of the 1:24,000 scale overlay will be drafted and the orthophotoquad and overlay will be mounted on a suitable backing.

2.2 Phase II

2.21 Transect locations were chosen to demonstrate principal vegetation types, vegetation patterns, environmental gradients, effects of man-made disturbances (e.g., ditches, roads, timber harvest, transmission line construction and ATV's) and natural disturbances (e.g., dwarf mistletoe infections, fire scars and beaver flooding).

2.22 Transect photography was accomplished in August and September using a two-camera unit -- a 28mm lens for continuous coverage at 1:80,000 and a 200mm lens for photoplots at 1:11,000.

2.23 1:120,000 scale 35mm CIR complete coverage (not specified in the contract) for both study areas was accomplished in July and September.

2.24 Internegatives and 3½x5-inch color prints were made of all the 35mm CIR photography. The 3½x5-inch color prints were taken into the field for ground truthing.

2.25 All the original CIR transparencies and internegatives have been indexed and filed for easy access.

2.26 Selected 3½x5-inch prints of the CIR photography will ultimately be board mounted for display alongside the corresponding 1:24,000 scale orthophotoquad.

3.0 Results to Date

3.1 Phase I

3.11 The third draft of the classification scheme is given in Appendix 5.0. Minor changes may yet need to be made. Following guidelines set down by the Peat Program, use of the terms bog and fen was avoided in the classification scheme due to the lack of widespread agreement as to their definitions.

3.12 Chase Brook SW Quadrangle was chosen for early completion and should be done in early January.

3.2 Phase II

All transect photography was successfully flown and is of generally good quality. Other investigators are invited to duplicate portions of this photography at their own expense. 3½x5-inch color prints currently cost about $.30 apiece. If interested, call Roy Hagen at 373-1412.

4.0 Discussion

The effect of the old drainage ditches on the hydrology and the plant communities of the Red Lake Peatland is probably greater than originally thought. This is particularly evident on the color infrared photography. Their effect on major watertracks is often dramatic; their effect on ombrotrophic raised bogs appears to be minor.

5.0 Appendix

(attached)

6.0 Recommendations for Additional Research

Future applications of remote sensing techniques to Minnesota's peatlands should be in response to needs identified by the Peat Program or by other investigators.

5.0 Appendix

DNR - PEAT

Classification Scheme - Third Draft

I. <u>Mineral Uplands</u> - Distinguished by discernible relief and characteristic vegetation types (not always well defined).

A. <u>Woody</u> - ≥10% canopy cover (no size, density or vigor classes)

N - Needleleaf evergreen forest (<10% cover of D)

D - Broadleaf Deciduous forest (<10% visible cover of N)

DN - Mixed; over 10% cover of both D and N

Sd - Deciduous Shrub; ≥10% and <90% visible cover (excludes shrubs under a forest canopy and, therefore, not visible on an aerial photograph)

B. <u>Nonwoody</u>- <10% cover of woody vegetation

Au - Agriculture; field or pasture (the u indicates an upland site)

AAu - Abandoned Agriculture (not used within the past year)

B - Bare soil (<50% vegetated and non-agricultural), e.g., a gravel pit

C. <u>Combined Types Expected</u>

DSd - 10-90% cover of D <u>and</u> 10-90% visible cover of Sd

DNSd, NSd

II. <u>Peatlands</u>

A. <u>Trees and Deciduous Shrubs</u>

1. Forest types - ≥10% cover

a. Species

Sp - Black spruce

Ms - Dwarf Mistletoe infection in black spruce

T - Tamarack

Sc - Swamp conifer; black spruce and/or tamarack (not differentiable on the photography)

C - Northern white Cedar

P - Aspen (Populus)

F - Black Ash (Fraxinus)

b. Vigor

— - Low vigor, tree stunted, less than 8m tall at maturity (antecedes symbols for tree species and height)

c. Height

a - <8m (antecedes symbol for tree species)

b - ≥8m

d. Density (Canopy cover)

' - 10-40% (antecedes symbols for species, height and vigor)

'' - 41-70%

''' - 71-100%

e. Other

Lg - Recently logged -- reproduction not present or too small to classify

f. Examples

- A stand of black spruce averaging 7m in height of good vigor with 80% canopy cover would be labelled Spa'''.

- A stand of stunted tamarack averaging 6m in height with 30% canopy cover would be labelled Ta— '. (NOTE: Any symbol for a forest type with less than 70% canopy cover must be anteceded by the appropriate symbol for the understory type.)

- A stand of 12m tamarack with 30% cover over mixed tamarack-black spruce 3m tall reproduction with 50% cover, but not differentiable by species on the photography would by typed Tb'/Sca''.

2. Deciduous shrubs over one meter tall - ≥10% visible cover

a. Species

W - Willow

WAl- Willow and/or Alder

B - Bog birch (Betula pumila) -- commonly occurs with an understory of ericaceous shrubs (ericads). When stunted (i.e., less than about 1.5m) it often cannot be diffentiated from the ericads and would be typed E.

WB - Willow and/or Bog Birch

b. Density - same as for forest types

B. Herb, Moss and Ericad Types

L - Leatherleaf; continuous cover of vigorous ericads -- predominately leatherleaf -- over a continuous sphagnum moss layer. Sedges are absent or of minor importance. Occurs where fire has burned a raised spruce bog.

M - Moss; continuous moss layer (usually of nearly pure Sphagnum spp.) with a variable cover of sedge and ericads, neither of which are continuous or vigorous, dry -- water table below the surface.

E - Ericads; continuous even cover of ericaceous shrubs with or without a moss layer underneath. Sedges absent or of minor importance. May include short bog birch. No a burned over raised spruce bog.

Mh - Wet Moss ((hydric); similar to M with a near continuous moss layer, but on a distinctly wetter site. Commonly found in association with S type. Ericads often dominant.

S - Sedge; <10% cover of sphagnum, water table at the surface through much of the year.

G - Graminoids; a mixture of grasses and sedges, found commonly on shallow peats and along ditches flooded by beaver dams.

Ut - Tamarack understory; used where understory in a tamarack stand does not fit any of the above types. Tamarack understories tend to be very diverse

C. Special Features

R - Ribbed pattern to the vegetation with the ribs or strings oriented roughly perpendicular to the direction of water movement.

Ti - Tamarack islands; long, narrow, raised "islands" <$7\frac{1}{2}$ acres in size and oriented parallel to the direction of water movement. A typical island has a stand of tamarack at the upstream head and a tail of ericads and/or bog birch. (Not all the islands have significant amounts of tamarack.)

Spi- Spruce islands; nearly circular small islands of black spruce (with some tamarack) over continutous sphagnum and near continuous ericads.

Lg - Logged over

A - Agriculture

AA - Abandoned Agriculture

D. Conventions

- No assumptions are made about shrub, herb or moss layers beneath an upper canopy, i.e., density or coverage classes only refer to the uppermost visible layer of vegetation as viewed on an aerial photograph.
- Only those vegetation types covering 10% of a type unit will be included in the classification of that type unit.
- Minimum size of a type unit is $7\frac{1}{2}$ acres.

- The general sequence of symbols in classifying a a type unit shall be:

  1. R, AA or Lg
  2. Tree species
  3. Deciduous shrub
  4. Herb, moss or ericat type
  5. Ti or Spi if these features are present

- If herb, moss or ericad types are combined, the symbol for the type having the greatest areal coverage shall come first. A ribbed peatland with the Mh type on the ribs and S between ridges would be labelled RSMh.

E. Examples:

Raised ovoid islands -- M, Spa— 'M, Spa— ''M, Spa''', L, Sca'L

Fen types -- S, RS, RSMh, RB'S, RB''S, SSpi, STi, RSTi, RB'STi

Transition types -- Mh, Ta— 'Mh, Ta'B'Mh

III. Other Symbols

Type line

Border between upland and peatland

→ Direction of water flow in a ditch as evidenced by beaver dams or ground observations

SECTION J

ANALYSIS OF MINNESOTA PEAT FOR POSSIBLE

INDUSTRIAL CHEMICAL USE

Progress Report - Dec. 15, 1978

Submitted by Charles H. Fuchsman

(Director, Center for Environmental Studies, Bemidji State University)

1. Authorization: The work done on this project is performed under contract 328062 between Minnesota Department of Natural Resources and Bemidji State University.

2. Expenses to date: The most recent printout shows expenditures and encumbrances for salaries and salary-related costs to be $9923, travel $30, supplies $494, lab equipment $329.

3. Activities up to December 8.

   a. On the basis of discussions with Tom Malterer of DNR, a program for collection of peat samples was established, with samples to be delivered to Bemidji State University for study. Of cores to be obtained from 30 sites in 6 peat areas, cores have already been delivered from 25 sites in 5 peat areas identified as Pine Island, Norman Lake, Baudette, Salol, and Meadowlands. A visit to a Pine Island site was made by Drs. Fuchman and Lundberg, accompanying Dr. H. Grumpelt, peat coke expert from Germany. Tom Malterer and his crew demonstrated their peat sampling technique.

   b. Preliminary tests were run to check the validity of the proposed methods of analysis and the suitability of equipment for the samples involved. On the basis of these tests appropriate procedures were selected for the determination of peat bitumens, ash, and phosphorus content. The bitumen content will indicate the commercial potential of the peat as a source of wax. Ash and phosphorus content will indicate possible value for the production of peat coke and activated carbon.

   c. Preparation of peat samples:

      All samples were air-dried to 5-10% residual moisture, and then ground in a Wiley mill to pass a 20 mesh screen. Oven drying was done only to determine residual moisture, since oven-drying appears to alter the character of peat and of its bituminous component. The air-dried ground samples were stored until needed.

4. Results of bitumen analysis. Bitumens were extracted for about 4-6 hours in a Soxhlet apparatus, using benzene-ethanol (2:1) as the solvent. (Note: all results represent raw data and may be corrected in the final report.)

Site		% Bitumens in air-dried peat			
		1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
Norman Lake	1	5.4	-	2.9	2.0
	2	3.1	8.2*	-	4.2
	3	4.0	3.9	4.2	4.2
	4	3.1	-	-	4.5
	5	5.4	4.6	2.8	3.0
Pine Island	1	7.0	-	-	-
	3	5.2*	-	-	4.0
	4	7.0	-	-	4.2**
	5	-	-	-	8.0
Solol	2	5.8	-	4.4	1.5
	3	4.0	7.1	7.1	4.1
	4.	6.2	-	3.2	-
Baudette	9	3.8	-	-	4.1
	11	7.4	5.4	4.0	-
	19	5.8	-	4.9	2.9

* Average of two analyses

** Average of two analyses; one aberrant value rejected

5. Results of analyses for ash content. Samples were ashed at 500°C in porcelain crucibles. Samples ashed at higher temperatures tended to fuse to the porcelain glaze. (Results are subject to correction in the final report.)

% Ash in air-dried peat

Site		1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.
Pine Island	1	5.1	4.2	4.2	3.5
	2	4.9	1.5	2.9	2.5
	3	7.7	4.0	2.8	2.4
	4	5.6	5.8	3.6	4.2
	5	8.3	7.1	12.0	12.0
Norman Lake NE	1	8.9	8.2	11.0	10.1
	2	9.3	7.5	8.2	8.3
	3	8.5	6.0	6.6	5.7
	4	7.9	7.7	10.5	8.9
	5	8.3	9.0	11.8	13.0
Baudette	1-19	8.2	-	-	9.6
	2-9	6.6	7.3	7.0	7.6
	3-11	8.2	7.5	8.8	11.5
	4-15	5.6	6.2	8.0	8.7
	5-7	6.2	5.9	8.7	8.6
Salol	1-2	5.2	5.6	7.0	9.7
	2-3	7.1	6.2	5.5	6.8
	3	6.1	5.6	5.6	6.0
	4	7.3	5.9	6.2	6.4
	5	6.1	-	-	6.6

6. Results of analysis for phosphorus content. The phosphorus was determined colorimetrically in the ash, using the molybdate-vanadate method. The samples are reported as parts of P per hundred parts of aie dried peat.

Site		1-2 ft.	4-5 ft.
Pine Island	1	0.032	0.034
	2	0.029	0.021
	3	0.033	0.024
	4	-	0.032
	5	0.056	0.036
Norman Lake NE	1	0.075	0.060
	2	0.061	0.046
	3	0.082	0.048
	4	0.070	0.061
	5	0.053	0.050
Baudette SW	1-19	0.049	0.048
	2-9	0.055	0.050
	3-11	0.055	-
	4-15	0.040	0.042
	5-7	0.039	0.048
Salol	1-2	0.046	0.026
	2-3	0.060	0.051
	3	0.051	0.053
	4	0.062	0.045
	5	0.063	-

7. Evaluation of results:

a. Bitumens. It may be assumed the wax content peat will commonly be about one-half to two-thirds of bitumen content. It is also likely that for wax contents less than 5%, peat cannot be economically harvested for peat production. Thus bitumen levels above 8% are required. For lower levels it may be possible to develop peat extraction of a by-product from peat used primarily for other purposes.

Virtually, no peat sampling sites appear to be rich enough in bitumens to warrant more commercial interest at present. The Pine Island Bog, however, had the largest portion of samples containing 7.0% or more bitumens.

b. Ash and phosphorus content.

Metallurgical grade peat coke may not have more than 0.06% P. Since coking reduces the weight of peat by 2/3 without removing any phosphorus, the air-dried peat should contain no more than 0.02% P. None of the samples so far are low enough. Samples from Pine Island bog have the lowest P values of those analyzed.

Ash contents are not as critical as P content. However preferred ash contents in peat coke and in activated carbon are less than 15%, which requires ash levels below 5% in the air-dried peat. About half the samples of Pine Island bog had an acceptable range of ash values for condensation as raw materials for coke or activated carbon.

8. Tentative conclusion:

Of the peat sampling sites so far examined, those at Norman Lake, Baudette, and Salol appear to be too low in bitumen content to support a peat wax operation, and too high in phosphorus to support a peat coke operation. Peat from the Pine Island bog appears to have higher bitumen content and lower phosphorus content than peat from the other bogs. It is of marginal interest, but may justify further study.

SECTION K

AN INSTITUTIONAL VIEW OF MINNESOTA'S PEATLANDS

The Peat Project Staff, together with the Mineral Leasing Section of the DNR and the Minnesota Department of Revenue has begun a joint study to assess the impacts various royalty and taxation combinations would have on horticultural peat development in Minnesota. The study design utilizes a computerized discounted cash flow model. A formal report is being prepared and should be available for distribution in February.