INVESTIGATIONS INTO THE EFFECTS OF ACID PRECIPITATION ON WETLAND-DWELLING WILDLIFE IN NORTHEASTERN ONTARIO

Peter J. Blancher
Donald K. McNicol

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Donald K. McNicol
Canadian Wildlife Service
Ontario Region
1725 Woodward Drive
Ottawa, Ontario
K1A 0E7

PREFACE

The loss and degradation of habitat is a major waterfowl management problem in North America today. Formerly secure waterfowl habitats in the vast continental boreal forest of eastern Canada are now affected by hydropower and recreational developments, certain forestry practices, and industrial effluent pollution and atmospheric contamination (NAWMP 1985). Loss or degradation of natural wetlands in the boreal forest may have serious implications for the future of the waterfowl resource in eastern North America. The ecological effects of industrial emissions, long range atmospheric transport and subsequent deposition of acidic substances, has received considerable attention over the past decade. Acidic deposition is believed to be responsible for widespread changes in surface water chemistry in northern Europe and northeastern North America, changes that have in at least some cases caused undesirable impacts on water quality and biota (Harvey et al. 1981, Memorandum of Intent 1983), including wildlife (Clark and Fischer 1981). However, there is not universal concensus that emissions of "acid gasses" from industrial sources, and its subsequent transport and deposition onto distant watersheds, is responsible for all chemical changes in surface waters (Rosenqvist 1978, Krug and Frink 1983). Proponents of alternative explanations for changes in surface water chemistry suggest that there are important natural sources of acidity in watersheds.

Concern for the potential threat to the waterfowl resource in Ontario prompted the Canadian Wildlife Service (Ontario Region) to undertake studies to determine the effects of acid precipitation on waterfowl populations in northern Ontario. These investigations have attempted to identify the mechanisms by which acid precipitation affects waterfowl, through its impact on prey species. The processes that determine whether acidity is limiting the quality and quantity of waterfowl foods at crucial stages in the nesting cycle has received considerable attention (Bendell and McNicol in prep. a, b; McNicol et al. 1986a, b). Of necessity, these studies have focused on waterfowl breeding in small, mostly clear headwater lakes. Relatively little work has been done in the coloured waters of wetlands, particularly concerning wetland-dwelling wildlife (Anderson 1985), primarily because many of these wetlands are naturally somewhat acidic, but also because they exhibit a relatively complex water chemistry. Recently, however, as part of the CWS (ONT) LRTAP program, geochemical and biological studies were extended from headwater lakes into peatland (bog and fen) habitats. Peatlands represent a major source of natural acidity in watersheds, and are a large and vital component of the biosphere. Widespread disruption of these ecosystems by acid rain and associated pollutants could have serious consequences for the freshwater lakes and streams receiving their drainage (Gorham et al. 1984). Peatlands also represent an important wildlife habitat in Canada (e.g. IEC Beak 1983), often supporting a unique flora and fauna (e.g. Oullet et al. 1976, Forman 1979), including many avian species that use peatlands for nesting and/or foraging (Brewer 1967, Erskine 1977). As part of the larger study of waterfowl populations on headwater lakes, this report summarizes the results of studies conducted in 1985 to assess the effects of airborne acidity on wildlife species and their prey that inhabit wetlands subject to natural acidification processes, so that comparisons of fauna and water chemistry between coloured and clearwater systems of similar acidity and depositional regimes can be made.

ABSTRACT

Northeastern Ontario peatlands were studied to examine differences in geochemistry and biota related to acid deposition. Bogs and poor fens at Wanapitei, an area that has received a high rate of acid deposition, were compared to bogs and fens at Ranger, where deposition has been lower.

Water samples from the surface of peatland mats were more organic than samples from open pools. Poor fens had higher concentrations of mineral elements than bogs. Peatlands at Wanapitei showed greater acidity, higher sulphate, and higher mineral and metal concentrations, in most comparisons with peatlands at Ranger. An analysis of hydrogen ion concentration suggested that both mineral and organic acidity were present in peatland waters. Sulphate tended to be the predominant anion in Wanapitei pools, whereas organic anions were more important at Ranger. These results suggest an influence of acid deposition on the chemistry of peatland waters.

Vegetation was responsive to chemical and physical gradients in peatlands. No direct influence of acid deposition on mat vegetation was apparent from comparisons of Wanapitei and Ranger peatlands.

Most aquatic organisms appeared to be negatively affected by acidity at some point within the range of pool pH's observed (3.9-7.3). A cyprinid-dominated fish community was present in fen pools with pH > 4.8. Most invertebrate taxa fell into two groups: those that were most abundant at higher pH, and those that responded positively to pH but only in the absence of fish. Successful breeding by amphibians was only apparent at pH 4.45 and above.

Wildlife inhabiting peatlands were documented. Invertebrates from peatland pools appeared to be an important source of food for many species of wildlife. A preliminary study of Tree Swallow nesting ecology was conducted as a possible indicator of effects of acid deposition on insectivorous wildlife in peatlands. More detailed information is needed to elucidate any negative effects of acid deposition on terrestrial wildlife that forage in wetlands. Differences in peatland acidity that parallel levels of acid deposition, and negative responses of aquatic organisms to acidity, indicate the potential for an impact on these wildlife.

RESUME

Les terrains tourbiers du nord-est de l'Ontario ont été étudiés afin d'examiner les différences en géo-chimie et biote relatives aux dépositions acides. Les marécages et les marais à Wanapitei, un endroit qui a reçu une quantité élevée de dépositions acides ont été comparés aux marécages et aux marais de Ranger, où les dépositions ont été moindres.

Des échantillons d'eau prélevées à la surface des tourbières étaient plus organiques que les échantillons des marais qui avaient des concentrations plus éleveés d'éléments minéraux. Les tourbières de Wanapitei ont démontré une acidité et un sulfate plus élevé, ainsi que des concentrations plus fortes de minéraux et de métaux, en comparaison de celles de Ranger.

Une analyse de concentration de cation a suggéré qu'une acidité minérale et organique était présente dans les eaux des terrains tourbiers. Le sulfate avait tendance à être l'anion prévalent dans les flaques d'eau à Wanapitei, tandis que les anions organiques étaient plus importants à Ranger. Les résultats suggèrent une influence de dépositions acides dans la chimie des eaux des terrains tourbiers.

La végétation était sensible aux gradients chimiques et physiques dans les tourbières. Il n'y avait aucune apparence d'influence directe de dépositions acides sur le tapis végétal des comparaisons entre les tourbières de Wanapitei et celles de Ranger.

La plupart des organismes aquatiques ont paru être affectés négativement par l'acidité à un point à l'intérieur des variations du pH observé (3.9 à 7.3). Une communauté composée de poissons principalement cyprinidés était présente dans les étangs marécageuses qui avaient un pH > 4.3. La plupart des invertébrés tombaient dans l'une ou l'autre de deux catégories: ceux qui étaient plus abondants à un pH plus élevé et ceux qui ont répondu positivement au pH mais seulement en l'absence de poissons. On a observé la reproduction avec succès des amphibiens seulement là où il ya avait un pH de 4.45 ou plus élevé.

La sauvagine qui habite les tourbières a été documentée. Les invertébrés dans les flaques d'eau des terrains tourbiers ont paru être une source de nourriture importante pour plusieurs espèces d'animaux sauvages. Une étude préliminaire de l'écologie de la nidification de l'hirondelle bicolore a été effectuée comme indicateur possible des effets des dépositions acides sur la faune insectivore des terrains tourbiers. Plus de renseignements détaillés sont nécessaires afin d'éclaircir tout effet négatif des dépositions acides sur la faune terrestre qui se nourrie dans les marécages. Des écarts entre l'acidité des tourbières qui comparent les niveaux de dépositions acides ont été démontrés. Les réactions négatives des organismes aquatiques à cette acidité indiquent le potentiel d'une influence sur la sauvagine.

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1. INTRODUCTION

The aim of this study is to investigate the impact of acid deposition on wetland-dwelling wildlife in northeastern Ontario. The study began in the fall of 1984 and is expected to continue through 1986. The present report summarizes the findings of the 1985 field season.

1.1 RATIONALE

Wetlands are an important wildlife habitat in Canada (e.g. Champagne 1981, IEC Beak 1983). Recently there has been evidence and speculation that certain types of wetlands (primarily peatlands) are susceptible to change through acid precipitation (Gorham et al. 1984). Bogs near industrial centres in Britain have lost all but the most tolerant of Sphagnum species over the last 250 years (Ferguson and Lee 1983), and the pH of bogwater is as much as 1 pH unit lower there than in non-industrial areas (Gorham 1958). Growth of several species of Sphagnum has been shown to be inhibited or reduced by sulphur in concentrations comparable to that in acid precipitation (Ferguson and Lee 1978, 1983). Bogwaters receiving high inputs of acid deposition in areas of Britain and Belgium are dominated by sulphate anions, indicating mineral acidity rather than organic acidity (Gorham 1958, Vangenechten 1981). Fens with values of about 6.0 and very low alkalinities are thought to be very susceptible to further acidification because they have little bicarbonate buffering (Gorham et al. 1984), but even bog waters with naturally low pH are thought to be susceptible to further acidification upon addition of sulphur compounds of anthropogenic origin (Johnson 1981).

These changes in wetland habitat should have important consequences for wetland-dwelling wildlife, but as yet, little is known about the effects of acid precipitation on wetland wildlife (Anderson 1985, Blancher 1985). The present study is designed to address this question.

1.2 APPROACH

Gorham et al. (1984) outlined three basic approaches for determining effects of acidic deposition on wetlands. The first is to compare historical data collected before acidification was a problem, with post-acidification data from the same study site, in order to determine changes that have occurred. Such an approach is often not possible due to lack of historical data, though past information on vegetation and chemistry can be inferred from peat core samples (e.g. Tallis 1964) or diatoms in pool sediments (e.g. Van Dam et al. 1980). A second approach is to experimentally acidify a wetland and compare pre- and post-acidification data. This approach is currently being used in the Experimental Lakes Area (ELA) of northwestern Ontario (e.g. Bayley and Schindler 1985). The third approach is to make geographic comparisons of wetlands across a gradient of acidic deposition (e.g. Urban et al. 1985). This latter method has been employed in the current study.

Our approach is to compare wetlands in two areas of northeastern Ontario differing in their current and historical inputs of acid deposition. The two study areas are: "Ranger" ($46^{\circ}55'$N Lat., $83^{\circ}35'$W Long.; 40 km northeast of Sault Ste. Marie), and "Wanapitei" ($46^{\circ}45'$N

Lat., 80°45'W Long.; 50 km northeast of Sudbury)(Fig. 1). While Ranger and Wanapitei are geographically quite close (225 km), Wanapitei has historically received much higher annual inputs of sulphate deposition from Sudbury smelting activities dating back to the 1930's (Fig. 1a,b). In 1977-1978, average annual bulk deposition levels of H^+ (63.2 ueq/m^2.yr), and SO_4^{2-} (70.0 ueq/m^2.yr) were recorded in collecting stations near Lake Wanapitei (Jeffries 1984). These measurements were substantially lower than historical levels and only slightly higher than similar measurements taken in Muskoka-Haliburton and other Shield areas (Scheider et al. 1979). Average annual bulk deposition levels of H^+ (63.6 ueq/m^2.yr) and SO_4^2 (63.7 meq/m^2.yr) have been recorded in the Turkey Lakes Watershed study (50 km northwest of Ranger Lake) since 1976, with an apparent decreasing trend underway. Wanapitei lies within a large zone of high sulphate deposition that extends to the northeast and southwest of the sulphide ore smelting centres in Sudbury. To minimize the effect of local deposition of metals (Cu, Ni, Zn and Fe) and dry deposition of SO_2, wetlands were selected beyond 40 km from the INCO Ltd. smelter at Copper Cliff. Both areas are centered in the same peatland region of North America (Zoltai and Pollett 1983)(Fig. 1c), along with the relatively unstressed wetlands being studied in the Experimental Lakes Area of Ontario (see Vitt and Bayley 1984, Bayley and Schindler 1985).

1.3 OBJECTIVES

The specific objectives of this report are to:

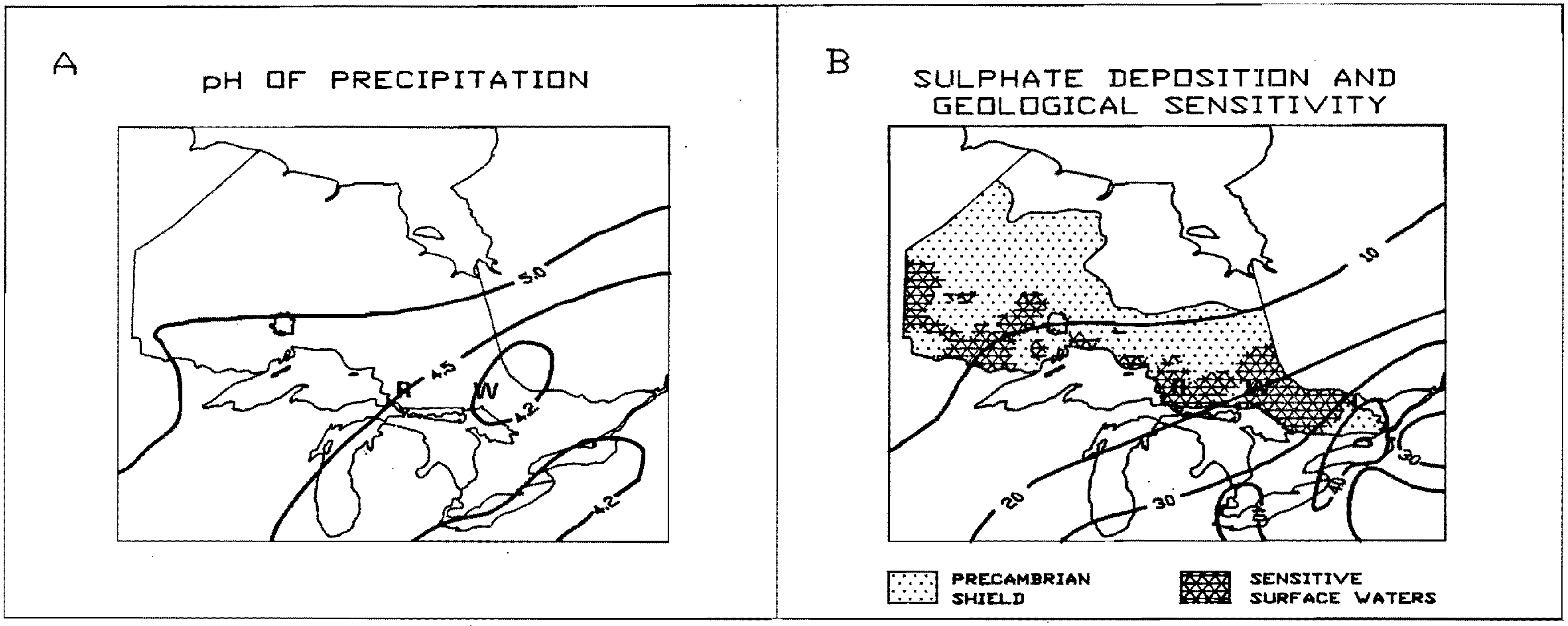
(1) describe the physical, chemical, floristic and faunal character of peatlands in the two study areas;

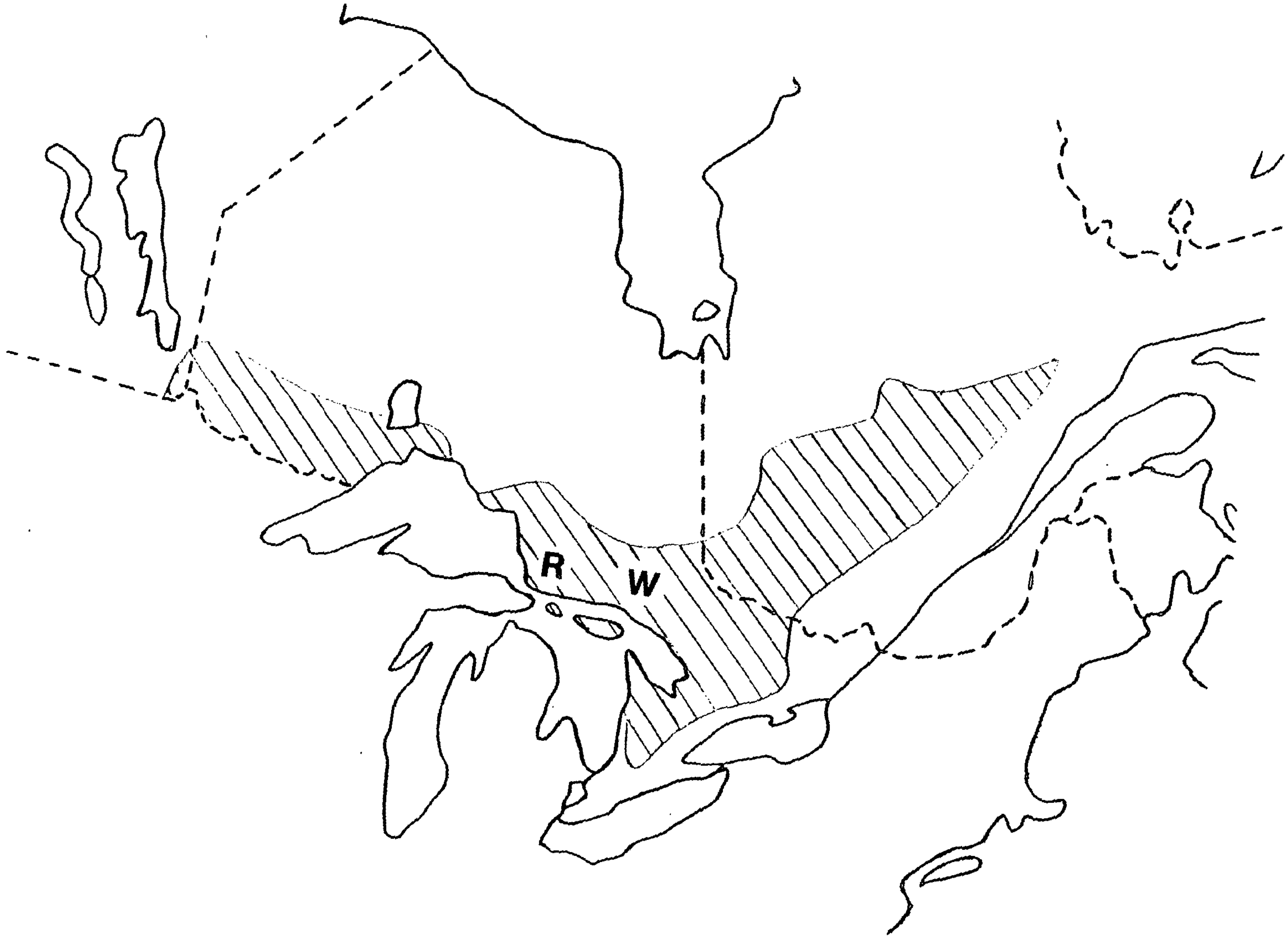
Figure 1: Maps of Ontario showing location of Ranger (R) and Wanapitei (W) study areas in relation to:

A - Precipitation amount - weighted mean annual pH in 1980 (from MOI 1983);

B - Mean annual wet sulphate deposition (Kg SO_4^{2-}/ha.yr) (from MOI 1983) showing outline of Precambrian Shield and sensitive surface waters (from Harvey et al. 1981);

C - Low Boreal Wetland Region (shaded, after Zoltai and Pollett 1983).


A
pH OF PRECIPITATION
5.0
4.5
4.2
R
W
4.2
B
SULPHATE DEPOSITION AND
GEOLOGICAL SENSITIVITY
10
20
30
30
40
PRECAMBRIAN
SHIELD
SENSITIVE
SURFACE WATERS


R
W

(2) determine differences in peatland water chemistry related to depositional differences;

(3) examine floristic composition in relation to chemistry of the wetlands;

(4) determine the responses of several groups of peatland fauna (aquatic invertebrates, small non-game fish, breeding amphibians, waterfowl, insectivorous birds, small mammals) to changes in acidity.

1.4 ORGANIZATION

The body of the report has been organized into the following sections:

- general description
- physical and chemical characteristics
- vegetation
- aquatic faunal community
- terrestrial wildlife
- summary

This sectioning has been done for ease of presentation and is not meant to imply that each unit functions separately of the others. An attempt is made to relate each part of the study to the next.

1.5 DEFINITION OF TERMS

Following are brief definitions for a number of terms used throughout this report to describe wetlands (after definitions in Zoltai et al. 1975, Monenco 1981, Gorham et al. 1984):

i) wetlands - areas that are poorly drained and thus at least periodically saturated with water.

ii) peatlands - wetlands with at least 30 cm accumulation of organic peat.

iii) bog - peatlands virtually isolated from mineral soil waters; with a surface cover of Sphagnum moss.

iv) fen - peatlands influenced by a supply of minerals from surrounding soils; with sedges forming a dominant component of vegetation.

v) poor fen - fens with a relatively weak mineral influence; vegetation intermediate between bogs and fens (Sphagnum and sedges often abundant).

vi) ombrotrophic - receiving all water and nutrients from precipitation.

vii) minerotrophic - enriched by water from adjacent mineral soils.

viii) oligotrophic - relatively low concentrations of minerals and nutrients. Used in this report to indicate conditions approaching ombrotrophy.

2. GENERAL DESCRIPTION OF THE STUDY SITES

The study areas are located primarily on Precambrian granitic bedrock which is moderately to highly sensitive to acidification. These study areas are described in more detail in McNicol et al. (1986b) in a report concerning acidification effects on waterfowl and other aquatic biota associated with headwater lakes.

Both areas lie in the Low Boreal Wetland Region (Zoltai and Pollett 1983) where wetlands comprise 5-25% of land area (Fig. 1c). Characteristic wetlands of this region are small bowl bogs and fens (i.e. peatlands), often tree-covered and surrounded by conifer swamps (Monenco 1981, Zoltai and Pollett 1983). Wetlands of this type have been classed as moderately to highly sensitive to acidification (Anderson 1985) because they have relatively small amounts of bicarbonate buffer.

2.1 STUDY WETLANDS

Peatlands were selected from aerial photographs on the basis of several criteria, including the presence of open water (thus many peatlands without open pools were excluded), small size (generally 1-7 ha), and access (usually within 1 km of roads or trails). Wetlands where pools were not completely surrounded by peatland vegetation were excluded. A total of 53 peatlands were examined in the field before choosing a sample of 31 core wetlands for detailed study (16 at Wanapitei, 15 at Ranger).

Selected wetlands were divisable into two types: treed bogs, and poor fens (Fig. 2). All treed bogs had central pools surrounded by a *Sphagnum* mat with ericaceous shrubs and at least 40% tree cover (mostly

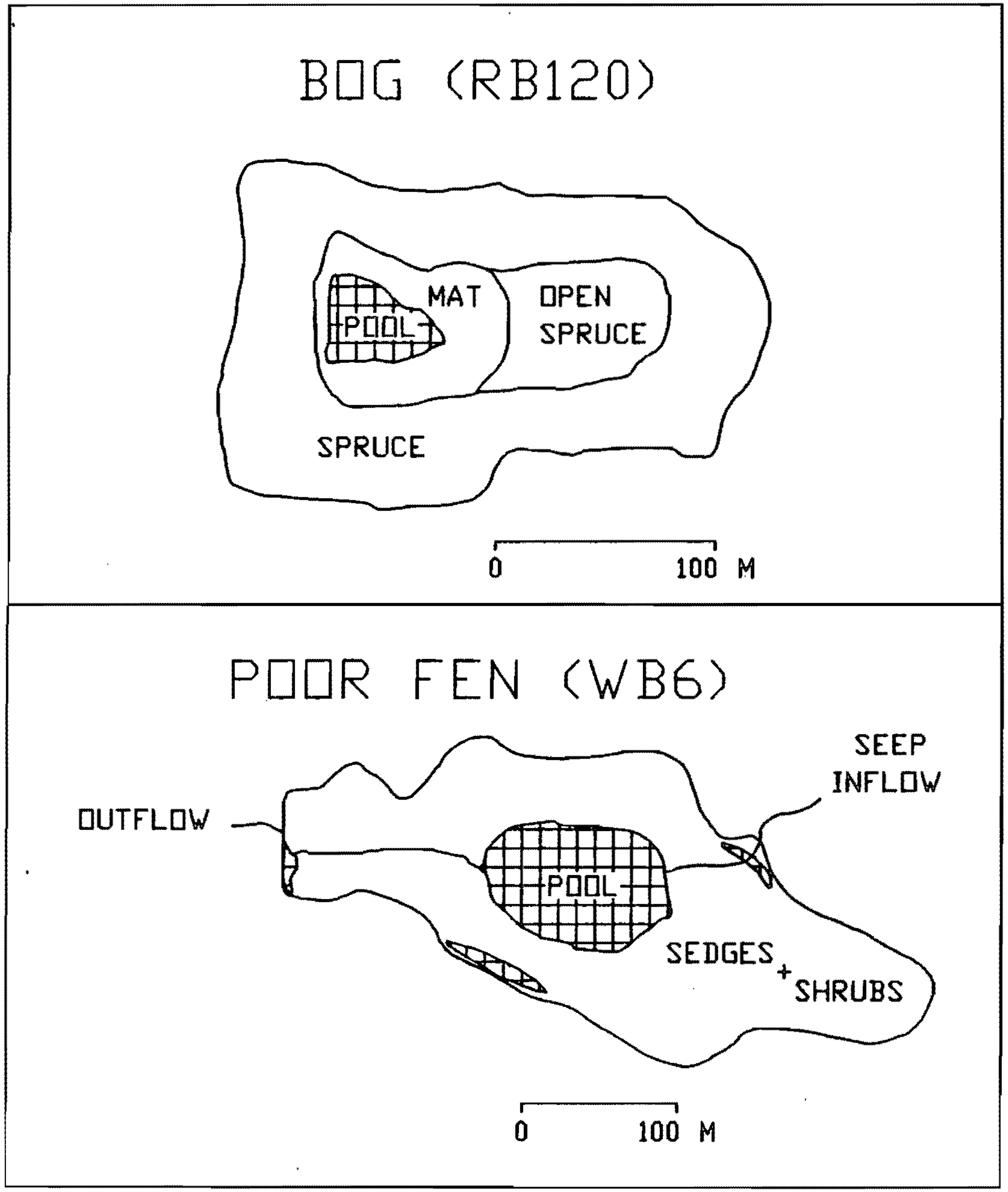


Figure 2: Examples of wetlands selected for study: treed bog at Ranger; poor fen at Wanapitei.

black spruce, Picea mariana. There were no noticeable inflows of water to these bogs, though some groundwater flow may be present. There were eight bogs at Wanapitei and seven at Ranger. Poor fens were dominated by a mix of sedges, ericaceous shrubs, and Sphagnum surrounding a central pool (Fig. 2). Trees were much less abundant in these peatlands. Eight poor fens were studied in each study area. The two classes of peatlands have distinctively different pool water chemistry (see next section), due to greater minerotrophic influence in the fens. All selected peatlands had at least 3 m measured depth of organic peat.

3. PHYSICAL AND CHEMICAL CHARACTERISTICS OF CORE WETLANDS

3.1 INTRODUCTION

The major underlying assumption of this study is that acid precipitation influences the chemical composition of peatland waters. In order to be able to show an impact of acid precipitation on wildlife, there must be a measurable impact on peatland water chemistry. As expected, headwater lakes in the Wanapitei study area are more acidified (low pH, reduced alkalinity, higher sulphate and metals) than lakes at Ranger (McNicol et al. 1986b), though the extent of acidification is influenced by bedrock and surficial geology, and by lake and drainage basin hydrology. Previous studies with peatlands have given contradictory results, some finding that mineral acid is neutralized in bogs (e.g. Hemond 1980, Bayley and Schindler 1985), others showing a decrease in pH and an increase in sulphate where acid deposition is highest (e.g. Gorham 1958, Vangenechten et al. 1981). The aim of this section of the report is to establish any chemical differences between wetlands in the two study areas which might be related to acid deposition.

The chemistry of large peatland pools or in lakes surrounded by bog mats can be very different from chemistry of water within peats nearby (Sjors 1959, Vitt and Slack 1975). Hemond (1980) suggested that this difference between pool water and peat water may explain the predominance of mineral acidity in British bogs sampled by Gorham (1958, water from bog pools) compared to the predominance of organic acidity in the Massachusetts bog that Hemond studied (interstitial water from peat). We have sampled both pool and surface mat water in this study so that both possibilities could be addressed.

Water chemistry in peatlands is strongly influenced by seasonal changes in water level (e.g. Groham 1956, Vangenechten et al. 1981). For this reason we obtained water samples in spring (period of high water), summer (low water), and fall (intermediate water level). Peatland chemistry is also likely to be influenced by physical characteristics of the wetlands. For example, differences in extent of open water or peat depth between study areas could lead to incorrect conclusions about the origin of chemical differences. For this reason we present some measures of morphology, hydrology and peat development.

3.2 METHODS

3.2.1 Physical Parameters

Wetlands were mapped from aerial photographs (scale 1:15,840), allowing measurements of total area, pool size, and area of treed peatland. Water depth within 1 m of the pool edge was taken in four places around each pool during July. The maximum of these four depths was used as an index of pool depth.

The presence of inflows and outflows was noted and was used as an indicator of minerotrophic influence (wetlands were classed as poor fens when outflows were present). Seasonal fluctuations in water level were monitored on 2.5 m wooden stakes driven into peat at the pool's edge. Stakes were first set and marked in mid-May (11-20 May), then checked six times between 23 May and 1 September, and again in early November (4th-11th). Disturbance to stakes by large mammals resulted in partial data loss in seven of the wetlands. In these cases, missing changes in water level were extrapolated from the rate of water level change in other periods in the same wetland, and from the seasonal pattern of water level change in wetlands with complete data.

A peat sampler with a maximum depth range of 12.5 m was used to obtain data on peat depth, peat humification and underlying bottom substrate. Peat cores were taken in two locations around the perimeter of the central pool, at a distance of 3-10 m from the pool edge. An additional core was taken in the centre of the treed zone of many of the bogs. Peat was sampled first at a depth of 0.4 m, then every 1.2 m until bottom, where an attempt was made to collect some of the underlying parent material. Peat humification was rated on the 10-point Von Post Scale (Jones et al. 1983), where scores of 1 to 4 indicate relatively undecomposed fibric peat, 5 to 6 - moderately decomposed mesic peat, and 7 to 10 - strongly to completely decomposed humic peat. Colour and clay content of the peat were also noted.

3.2.2 Chemical Parameters

Water samples were collected from pools and from the mat surface for all core wetlands during three seasons in 1985:

Spring	- Wanapitei	- 20	May
	- Ranger	- 21-22	May
Summer	- Wanapitei	- 17-19	August
	- Ranger	- 25-26	August
Fall	- Wanapitei	- 2-3	November
	- Ranger	- 6-7	November

Many of the wetland pools were also sampled in mid-November 1984. Chemical data from November 1985, and metal data from August 1985 were unavailable at the time of writing. Most chemical information presented in this report is from spring and summer 1985 when all core wetlands were sampled.

Mat surface water was collected by pressing the sampling bottle into wet depressions in the peat surface. Pool water was collected by grab sampling near the pool edge. All samples were kept cool until taken to the Great Lakes Forest Research Centre, Sault Ste. Marie. All samples underwent coarse filtering using a Wheaton No. 4 filter to remove suspended particulate matter. Samples prepared for nutrient and carbon analyses were filtered further using a 0.45 um millipore filter. Samples were analysed for the following elements: pH, conductivity, Total inflection point (TIP) alkalinity, water colour, Ca, Mg, Na, K, Cl, SiO_2, SO_4, NH_3, NO_3NO_2, PO_4, Fe, Pb, Al, Mn, Cu, Zn, Ni, Cd, total dissolved carbon (TDC), dissolved organic carbon (DOC), and dissolved inorganic carbon (DIC). Chemical determinations, procedures and equipment are as outlined in the MOE (1979) guidelines, except for the following: TIP alkalinity was measured by electrometric titration methodology equivalent to the Gran technique; sulphate and chloride measurements were analysed by the ion chromatography method due to bias associated with the methyl-blue technique in coloured waters (Kerekes et al. 1984); and water colour determinations (expressed in A.P.H.A.-Hazen Platinum-Cobalt colour units) were made on filtered samples using a Hellige Aqua Tester. Cadmium concentrations were not measurable in most samples (< 1.0 ug/l) so are not further considered in this report.

Conductivity was standardized to $20^{o}C$, and then corrected for hydrogen ion concentration (K_{corr}) using methods presented by Sjors

(1950). Organic anion concentration (A^-) was estimated from DOC concentrations using formulae presented by Oliver et al. (1983). Calculations of the percent of total anions included SO_4, Cl, NO_3, alkalinity (HCO_3), and organic anions.

Statistical tests are non-parametric (Wilcoxon tests, sign-rank tests for paired comparisons, Spearman rank correlations) unless otherwise noted. Before performing principal components analysis, all variables except pH were log-transformed. The SAS program FACTOR (SAS 1982) was used with varimax rotation to reduce the chemical variables to major axes.

3.3 RESULTS

3.3.1 Physical Parameters

Peatlands were small, ranging from 1.1 to 6.3 hectares with the exception of one large bog at Wanapitei (26.8 ha). Fens selected for study tended to be larger than the treed bogs and had larger central pools (Table 1). There were no study area biases in pool or peatland size. Within each peatland type, pools showed a great variability in size, with three pools only 0.01 ha in size, ranging up to 1.5 ha for the largest. Littoral water depth measurements indicated that bog pools at Wanapitei may have been shallower than fen pools or bog pools at Ranger (Table 1).

All peatland pools showed a drop in water level from May to August with a partial recovery by early November. It is possible that the lowest water levels would have occurred sometime after the August measurement. This drop in water level ranged from 3 cm to 21 cm with a mean of 10.4 cm. Water level drop did not differ consistently between Wanapitei and Ranger or between bogs and fens (Table 1). The seasonal pattern of water level increase did show a consistent difference between the two study areas however (Fig. 3). Water level dropped more rapidly at Wanapitei in the spring, and had not recovered as far by November as the Ranger pools. Nevertheless, at the times of spring and summer water sampling, relative water levels were similar in the two study areas (i.e. near maximum in May, near minimum in August).

Maximum peat depth near pools ranged from 4.8 to 11.6 m (Fig. 4). Such depths illustrate the bowl-shaped nature of these small

Table 1: Physical and morphometric features of selected peatlands. Values presented are medians, with ranges in parentheses.

	BOGS		FENS	
	Ranger	Wanapitei	Ranger	Wanapitei
Number of peatlands	7	8	8	8
Area (ha)	1.9 (1.1-5.2)	2.0 (1.2-26.8)	3.1 (1.6-6.3)	3.3 (2.0-4.6)
Pool Size (ha)	.14 (.11-.50)	.15 (.01-.24)	.55 (.03-1.43)	.49 (.22-1.48)
Mat Area (ha)	0.2 (0.1-0.5)	0.4 (0.2-6.5)	1.8 (0.4-5.4)	1.4 (0.5-4.1)
Treed Area (ha)	1.6 (0.7-4.5)	1.5 (0.6-19.4)	0.8 (0.0-4.0)	0.8 (0.0-3.2)
Water Depth (m)	1.2 (1.0-2.5)	0.5 (0.2-2.0)	1.1 (0.3-2.0)	1.2 (0.8-2.0)
Water Drop (mm)	84 (33-144)	114 (53-199)	122 (56-209)	88 (30-153)
Peat Depth (m)	8.6 (4.8-9.5)	7.9 (5.4-11.6)	8.4 (5.5-10.3)	8.1 (5.5-11.3)
Number of peatlands with the following underlying mineral substrate:				
Rock	1	0	1	2
Sand, Gravel	3	4	4	5
Clay	3	4	3	1

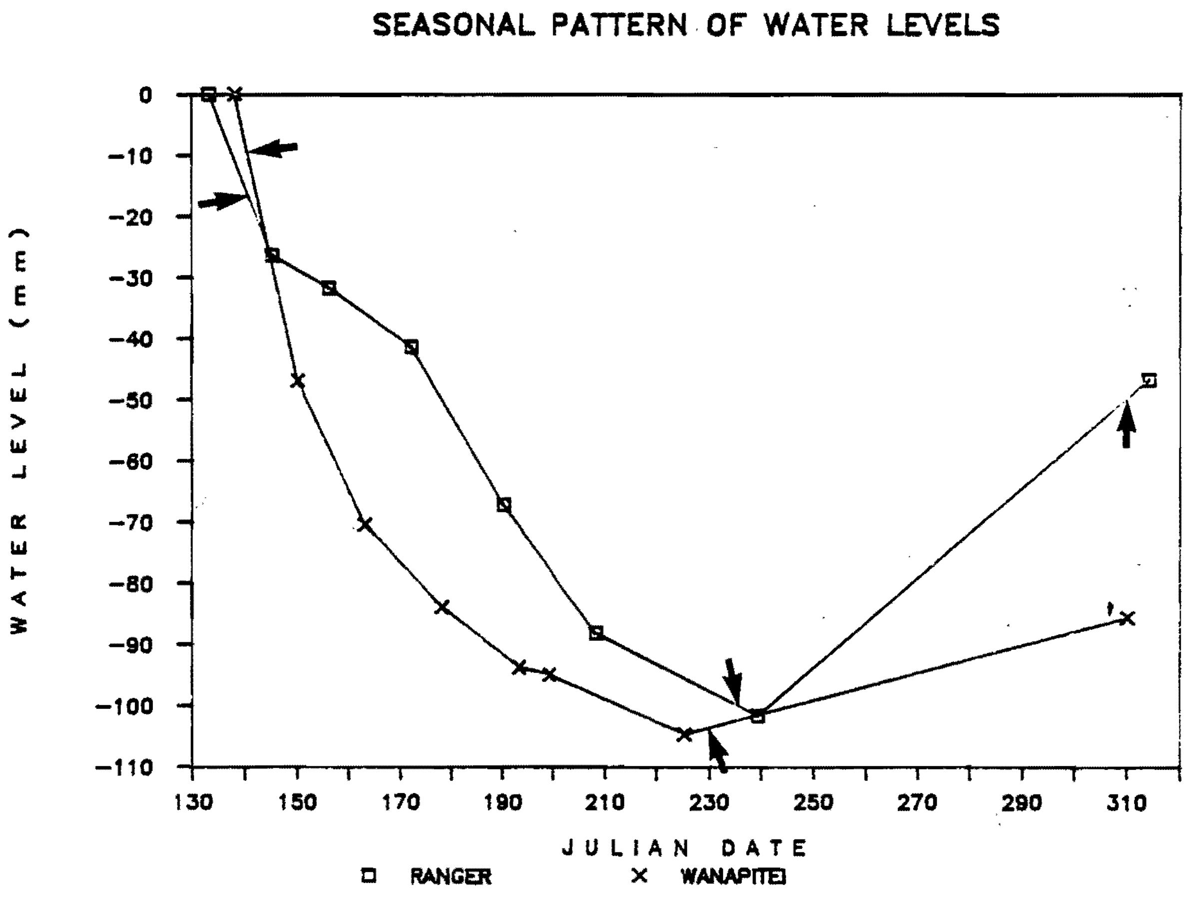


Figure 3: Seasonal patterns of water level decline in peatlands at Ranger and Wanapitei measured in 1985. Arrows indicate dates of spring, summer and fall water chemistry sampling.

peatlands, and probably explain the presence of open water pools. There was no tendency for peat depth to be related to the size of the central pool however. Peat depths taken at a distance of at least 30 m from the central pool tended to be shallower, ranging from 2.1 m to 7.9 m. There were no consistent differences in peat depth between bogs and fens or between Wanapitei and Ranger (Table 1).

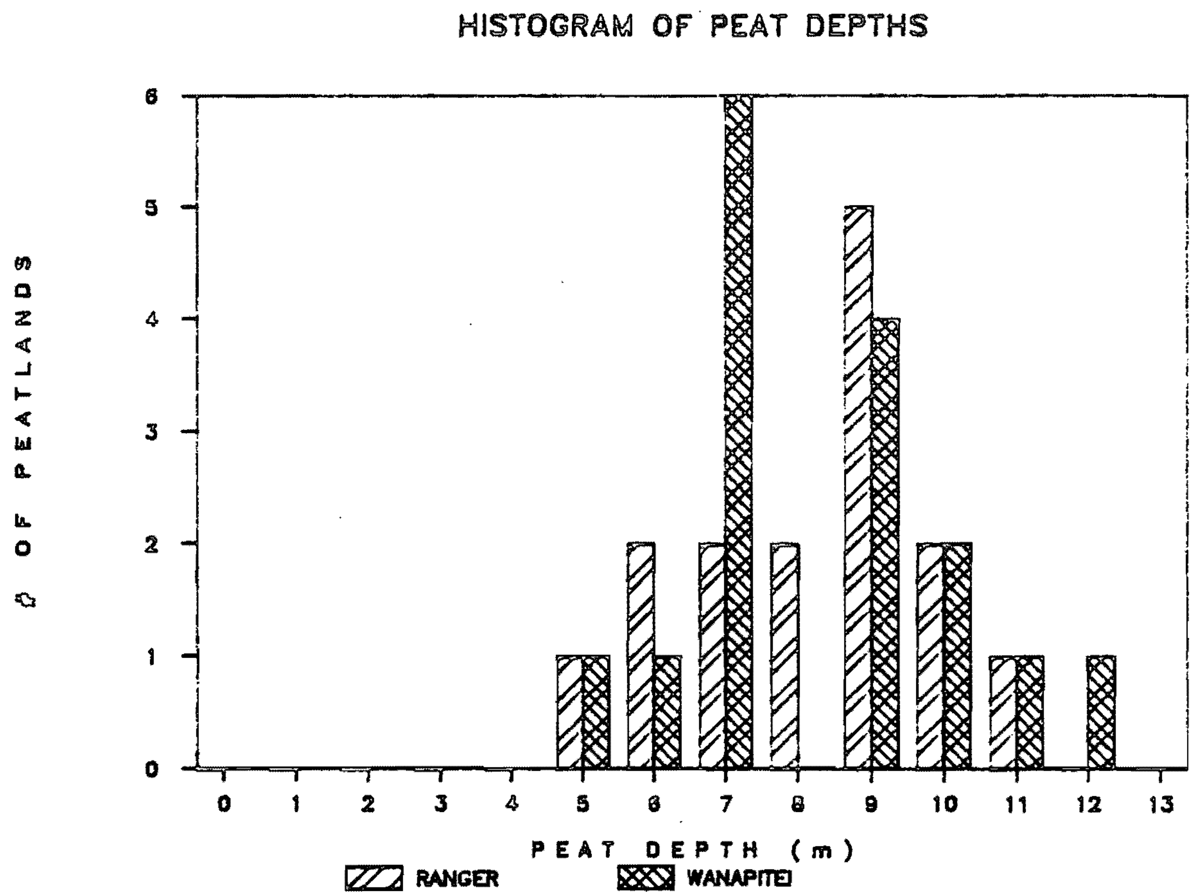
Peat humification profiles show a rapid transition from fibric to humic peat between 1.5 and 3.5 m in depth (Fig. 5). More than 50% of the peat profile is comprised of well-decomposed humic peat in both bogs and fens. This humic peat tended to be greenish in colour and often somewhat clay-like in samples near the bottom of the profile. The underlying substrate ranged from thick clay, through sand and gravel to rock (Table 1), with no apparent relationship to the type of peatland that developed above.

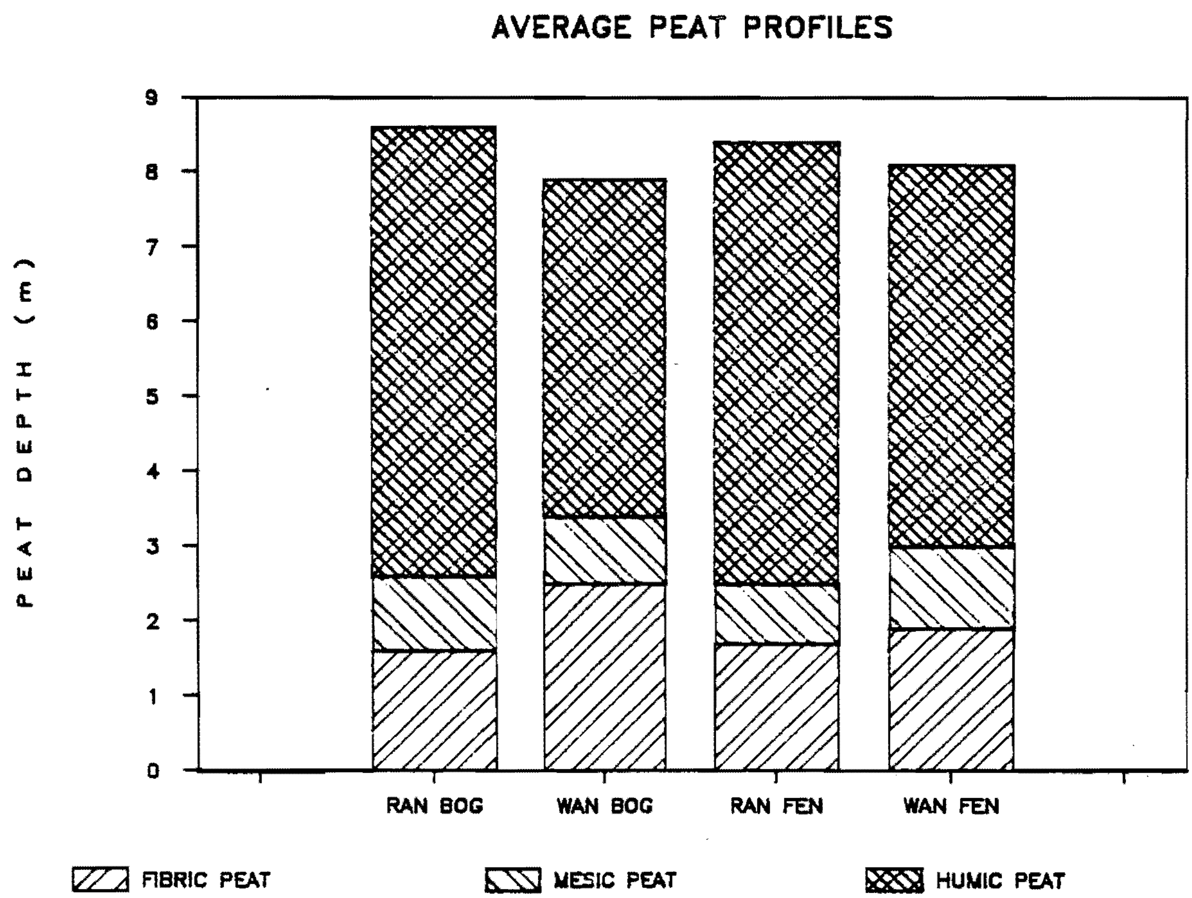
3.3.2 Chemistry

Most of the water chemistry variables could be placed into two groups, mineral and organic, based on positive correlations between members of each group (Fig. 6). Elements which tend to indicate mineral conditions include corrected conductivity, Ca, Mg, Na, SO_4, and to a lesser extent, SiO_2, Al, pH, and alkalinity. Organic conditions are represented by water colour, dissolved carbon (both organic and inorganic), PO_4, and to a lesser extent, Cl plus the metals Pb, Cu, Zn, and Fe.

Figure 4: Frequency distribution of maximum peat depths measured in each study area.

Figure 5: Average peat humification profiles for bogs and fens in the two study areas. Peat types were delineated by Von Post humification scores (see text).


HISTOGRAM OF PEAT DEPTHS
OF PEATLANDS
0
1
2
3
4
5
6
0 1 2 3 4 5 6 7 8 9 10 11 12 13
PEAT DEPTH (m)
RANGER
WANAPITEI


AVERAGE PEAT PROFILES
PEAT DEPTH (m)
0
1
2
3
4
5
6
7
8
9
RAN BOG
WAN BOG
RAN FEN
WAN FEN
FIBRIC PEAT
MESIC PEAT
HUMIC PEAT

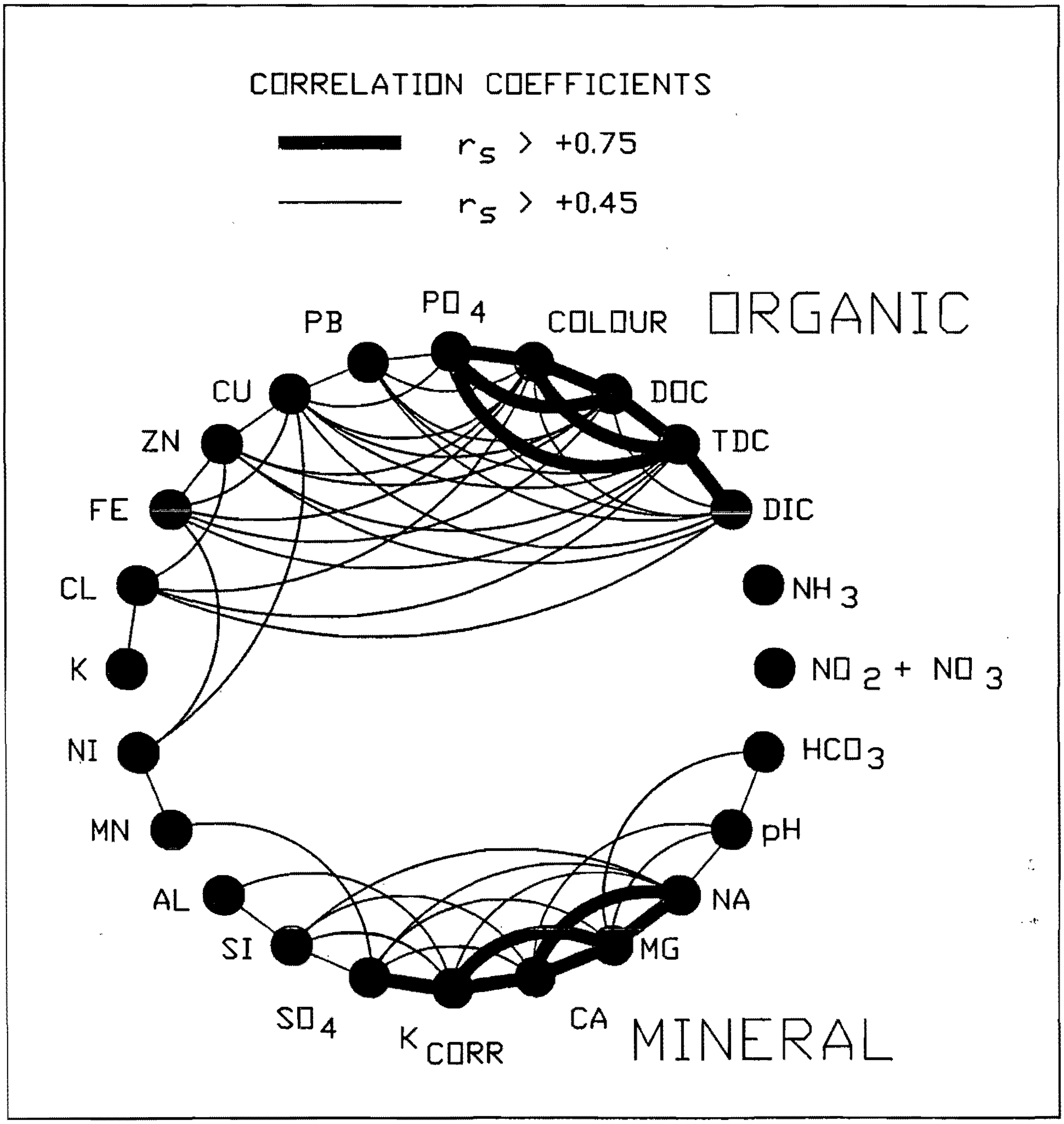


Figure 6: Natural groupings of water chemistry variables illustrated by positive correlations between variables (spring 1985 chemistry).

Table 2: Factor loadings for spring chemical parameters on first two factor axes. Factor analysis was done on 62 pool and mat samples. Only those loadings with absolute value .35 or greater are shown. Factor 1 is an axis of minerotrophy, factor 2 organics.

Chemical Variable	Factor 1	Factor 2
Ca	.93	
K_{corr}	.92	
Mg	.92	
Na	.80	
SiO_2	.66	
SO_4	.65	−.46
pH	.59	−.40
TIP alk.	.45	
Al	.43	
DOC		.89
Colour		.86
PO_4		.75
DIC		.72
Cu		.70
Fe		.68
Zn		.46
Cl		.35

A factor analysis on spring water chemistry illustrates the same groupings in a different way (Table 2). The first factor, which has high loadings of several mineral elements, accounted for 25.2% of the chemical variation. The second factor, with high loadings for organic elements, accounted for an additional 22.1% of the variation. Differences in minerotrophic influence, such as between bogs and fens, should be apparent among the first group of variables, while the independence of pool from mat samples should be measured by differences in the organic group.

3.3.2.1 Bogs versus Fens

As expected, fen pools at both Wanapitei and Ranger showed greater mineral influence than bogs (Table 3). Fens had higher pH, corrected conductivity (K_{corr}), alkalinity, calcium, Mg, Na, SiO_2, and Cl in most comparisons. Bog pools had higher concentrations of some metals, Mn and Zn at Ranger, Pb and Cu at Wanapitei. Organic variables tended to be unimportant in comparisons of bogs vs. fens, though bogs at Wanapitei had higher springtime levels of colour and organic carbon than fens. These organic differences disappeared in summer.

Comparisons of mat samples, however, did not show consistent differences for either mineral or organic variables. This may indicate that the classification of the peatlands into bogs and poor fens on the basis of hydrology is valid for the pools, but not necessarily for the mat.

Table 3: Comparison of the chemistry of bog versus fen waters as measured in 1985. Values presented are medians. Statistical differences: * $P < 0.05$, ** $P < 0.01$, Wilcoxon tests.

	Pool Samples				Mat Samples			
	Ranger		Wanapitei		Ranger		Wanapitei	
	Bog	Fen	Bog	Fen	Bog	Fen	Bog	Fen
N =	7	8	8	8	7	8	8	8
<u>Spring</u>								
K_{corr} (umho/cm)	10.8	* 20.0	20.9	25.7	8.3	10.7	13.9	13.6
Ca (mg/l)	0.45	** 2.20	1.30	* 2.41	0.44	0.83	0.78	0.93
Mg (mg/l)	0.16	** 0.54	0.39	** 0.59	0.14	0.30	0.22	0.27
Na (mg/l)	0.35	* 0.59	0.51	** 0.72	0.33	0.46	0.44	* 0.62
SiO_2 (mg/l)	1.74	2.56	2.14	* 3.72	1.53	1.08	2.70	2.21
SO_4 (mg/l)	2.51	* 5.16	8.06	9.18	1.20	1.16	3.06	1.57
pH	4.45	** 5.66	4.17	** 5.42	4.38	4.73	3.98	** 4.49
Alk. (ueq/l)	0.0	34.5	0.0	* 9.9	0.0	0.0	0.0	0.0
Al (ug/l)	49	114	191	129	127	62	111	** 83
Mn (ug/l)	19.0	* 14.6	43.5	47.1	9.8	9.4	17.8	22.2
Colour (hazen)	60	60	70	* 53	150	150	150	150
TDC (mg/l)	13.4	12.8	15.4	* 11.3	24.1	23.9	34.0	33.4
DOC (mg/l)	11.9	10.7	14.0	** 9.6	19.6	20.5	29.0	28.5
A^- (ueq/l)	72	89	81	79	120	147	156	186
DIC (mg/l)	1.6	2.0	2.0	1.6	3.3	3.8	4.5	3.9
PO_4 (ug/l)	1.55	1.25	1.47	1.42	2.22	2.48	2.95	3.02
Cu (ug/l)	0.0	* < 1	2.4	* 1.4	1.8	1.6	4.1	7.9
Fe (ug/l)	97	95	215	235	110	119	480	690
Pb (ug/l)	< 1	< 1	1.2	** < 1	1.5	1.0	1.8	1.4
Zn (ug/l)	6.9	* 3.9	7.6	7.0	20.0	19.2	18.4	21.6
Cl (mg/l)	0.18	* 0.28	0.16	** 0.20	0.49	0.47	0.35	* 0.59
K (mg/l)	0.24	0.24	0.15	** 0.25	0.34	0.38	0.13	* 0.45

Table 3 (cont.)

	Pool Samples				Mat Samples			
	Ranger		Wanapitei		Ranger		Wanapitei	
	Bog	Fen	Bog	Fen	Bog	Fen	Bog	Fen
N =	7	8	8	8	7	8	8	8
<u>Spring</u>								
Ni (ug/l)	< 1	< 1	9.8	8.5	1.4	* < 1	9.8	9.1
NO_2NO_3 (ug/l)	10.3	19.2	7.1	10.0	10.0	7.4	7.4	0.0
NH_3 (ug/l)	36.8	35.4	15.4	18.5	48.1	45.5	25.3	34.0
<u>Summer</u>								
K_{corr} (umho/cm)	5.6	** 20.7	13.1	* 21.8	10.9	* 17.2	17.2	17.6
Ca (mg/l)	0.50	** 2.78	1.34	* 2.24	0.75	1.20	1.44	1.31
Mg (mg/l)	0.15	** 0.74	0.35	** 0.51	0.27	* 0.45	0.35	0.31
Na (mg/l)	0.23	** 0.67	0.43	** 0.71	0.31	* 0.43	0.59	0.54
SiO_2 (mg/l)	0.03	** 1.87	0.42	* 0.89	0.83	1.39	1.52	1.98
SO_4 (mg/l)	2.48	2.94	5.92	6.29	2.22	3.70	6.21	4.56
pH	4.39	** 6.19	4.08	** 5.32	3.92	4.00	3.81	3.89
Alk. (ueq/l)	0.0	** 56.1	0.0	5.2	0.0	0.0	0.0	0.0
Colour (hazen)	65	100	63	68	280	280	388	430
TDC (mg/l)	14.3	16.0	14.2	13.1	37.6	32.5	50.7	44.3
DOC (mg/l)	13.5	14.5	12.8	11.5	35.4	31.4	47.0	41.9
A^- (ueq/l)	82	** 134	73	97	183	194	233	241
DIC (mg/l)	1.0	** 1.7	1.1	2.2	1.8	1.5	2.5	2.5
PO_4 (ug/l)	1.91	2.52	1.50	1.64	2.79	2.83	4.07	4.14
Cl (mg/l)	0.12	* 0.29	0.24	* 0.34	0.49	* 0.74	0.88	0.78
K (mg/l)	0.04	* 0.26	0.04	0.10	0.88	1.21	1.00	1.09
NO_2NO_3 (ug/l)	0.0	* 2.5	8.5	12.0	4.0	4.0	17.0	33.5
NH_3 (ug/l)	75	75	161	153	122	167	258	270

3.3.2.2 Pool versus Mat

Mat samples generally contained a great deal more organics than pool samples, especially in the summer when water levels were low (Table 4). Colour, organic and inorganic carbon, organic anions, PO_4, NH_3, Cl, and several of the metals (Pb, Zn, Fe, Cu) were consistently at higher concentrations in mat samples than in pool samples. In addition there tended to be less minerotrophic conditions in the mats than in the pools, at least in the spring. Levels of pH, conductivity, Ca, Mg, SO_4, and Mn were low in spring mat samples, while in summer pH was the only variable that was consistently lower in mat samples.

These differences between pool and mat samples allow us to evaluate the influence of mat water on pools of different size. If small pools are more heavily influenced by the presence of the mat, then we would expect to find a correlation between pool size, or pool depth, and organics. In fact, for fen pools there is no correlation between DOC in the pools and either pool area or pool depth. For bog pools, pool area is negatively correlated with organic carbon in summer (r_s = -0.53, df = 13, $P < 0.05$), but not in the spring. Water depth is negatively correlated with DOC in the spring (r_s = -0.73, df = 13, $P < 0.01$), but not in the summer. Both of these relations are largely a result of the highest measures of DOC being in two small shallow pools at Wanapitei (0.01 and 0.11 ha in size, 0.2 and 0.3 m deep). These two pools had organic carbon levels similar to mat samples in the spring (16.3 and 28.9 mg/l in pools, 17.0 and 28.8 mg/l in mat samples), but lower than mat samples in summer (27.9 and 34.8 mg/l in pools, 45.8 and 53.8 mg/l in mats). Other wetlands showed greater differences between pool and mat

Table 4: Paired comparisons of the chemistry of pool versus mat waters as measured in 1985. Values are medians. Statistical differences: * $P < 0.05$, ** $P < 0.01$, Sign-rank tests.

	Bog Samples						Fen Samples					
	Ranger			Wanapitei			Ranger			Wanapitei		
	Pool		Mat	Pool		Mat	Pool		Mat	Pool		Mat
N =	7		7	8		8	8		8	8		8
Spring												
K_{corr} (umho/cm)	10.8		8.3	20.9	*	13.9	20.0	**	10.7	25.7		13.6
Ca (mg/l)	0.45		0.44	1.30	*	0.78	2.20	**	0.83	2.41		0.93
Mg (mg/l)	0.16		0.14	0.39	*	0.22	0.54	**	0.30	0.59	*	0.27
Na (mg/l)	0.35		0.33	0.51		0.44	0.59		0.46	0.72		0.62
SiO_2 (mg/l)	1.74		1.53	2.14		2.70	2.56		10.8	3.72		2.21
SO_4 (mg/l)	2.51	*	1.20	8.06	*	3.06	5.16	**	1.16	9.18	**	1.57
pH	4.45		4.38	4.17	*	3.98	5.66	**	4.73	5.42		4.49
Alk. (ueq/l)	0.0		0.0	0.0		0.0	34.5	*	0.0	9.9		0.0
Al (ug/l)	49		127	191		111	114		62	129	**	83
Mn (ug/l)	19.0	*	9.8	43.5	*	17.8	14.6		9.4	47.1		22.2
Colour (hazen)	60	*	150	70	**	150	60	**	150	53	**	150
TDC (mg/l)	13.4	**	24.1	15.4	**	34.0	12.8	**	23.9	11.3	**	33.4
DOC (mg/l)	11.9	*	19.6	14.0	*	29.0	10.7	**	20.5	9.6	**	28.5
A^- (ueq/l)	72	*	120	81	*	156	89	**	147	79	**	186
DIC (mg/l)	1.6	**	3.3	2.0	*	4.5	2.0		3.8	1.6	*	3.9
PO_4 (ug/l)	1.55		2.22	1.47		2.95	1.25	**	2.48	1.42		3.02
Cu (ug/l)	0.0	*	1.8	2.4		4.1	< 1	**	1.6	1.4	*	7.9
Fe (ug/l)	97		110	215	**	480	95		119	235	*	690
Pb (ug/l)	< 1		1.5	1.2		1.8	< 1		1.0	< 1		1.4
Zn (ug/l)	6.9	**	20.0	7.6	**	18.4	3.9	**	19.2	7.0	**	21.6
Cl (mg/l)	0.18	*	0.49	0.16	**	0.35	0.28	*	0.47	0.20	**	0.59
K (mg/l)	0.24		0.34	0.15		0.13	0.24		0.38	0.25		0.45

Table 4 (cont.)

	Bog Samples						Fen Samples					
	Ranger			Wanapitei			Ranger			Wanapitei		
	Pool		Mat	Pool		Mat	Pool		Mat	Pool		Mat
N =	7		7	8		8	8		8	8		8
Spring												
Ni (ug/l)	< 1		1.4	9.8		9.8	< 1		< 1	8.5		9.1
NO_2NO_3 (ug/l)	10.3		10.0	7.1		7.4	19.2	*	7.4	10.0		0.0
NH_3 (ug/l)	36.8		48.1	15.4		25.3	35.4		45.5	18.5	*	34.0
Summer												
K_{corr} (umho/cm)	5.6	**	10.9	13.1	*	17.2	20.7		17.2	21.8		17.6
Ca (mg/l)	0.50		0.75	1.34		1.44	2.78	**	1.20	2.24		1.31
Mg (mg/l)	0.15		0.27	0.35		0.35	0.74		0.45	0.51		0.31
Na (mg/l)	0.23		0.31	0.43	**	0.59	0.67	**	0.43	0.71		0.54
SiO_2 (mg/l)	0.03	**	0.83	0.42		1.52	1.87		1.39	0.89		1.98
SO_4 (mg/l)	2.48		2.22	5.92		6.21	2.94		3.70	6.29		4.56
pH	4.39	**	3.92	4.08		3.81	6.19	**	4.00	5.32	**	3.89
Alk. (ueq/l)	0.0		0.0	0.0		0.0	56.1	*	0.0	5.2		0.0
Colour (hazen)	65	**	280	63	*	388	100	*	280	68	**	430
TDC (mg/l)	14.3	**	37.6	14.2	**	50.7	16.0	*	32.5	13.1	**	44.3
DOC (mg/l)	13.5	**	35.4	12.8	**	47.0	14.5	**	31.4	11.5	**	41.9
A^- (ueq/l)	82	*	183	73	**	233	134	**	194	97	**	241
DIC (mg/l)	1.0		1.8	1.1	*	2.5	1.7		1.5	2.2		2.5
PO_4 (ug/l)	1.91	**	2.79	1.50	*	4.07	2.52		2.83	1.64	**	4.14
Cl (mg/l)	0.12	**	0.49	0.24	*	0.88	0.29	**	0.74	0.34	*	0.78
K (mg/l)	0.04	**	0.88	0.04	*	1.00	0.26	*	1.21	0.10	*	1.09
NO_2NO_3 (ug/l)	0.0	*	4.0	8.5		17.0	2.5		4.0	12.0	*	33.5
NH_3 (ug/l)	75.	*	122.	161.	*	258.	75.	**	167.	153.	**	270.

organic levels in both spring and summer.

3.3.2.3 Wetland Pools versus Headwater Lakes

Another way of looking at the influence of the peat mat on wetland pools is to compare pool chemistry with headwater lake chemistry. Here we present data on headwater lakes sampled in the Wanapitei (N = 55) and Ranger (N = 69) study areas in mid-June 1983 (cf. McNicol et al. 1986b). Because the data were taken in different years, no statistical tests are presented. A comparison of the lake data with wetland pool data (Table 5) shows that headwater lake water chemistry is very similar to fen pool chemistry, despite the fact that headwater lakes have little development of organic mat around them and a lower water colour than peatland pools.

3.3.2.4 Wanapitei versus Ranger

Both bogs and fens showed chemical differences in comparisons between the Wanapitei and Ranger study areas. Bog pools were more acid at Wanapitei, despite the fact that mineral elements such as conductivity, Ca, Mg, Na, and SiO_2 tended to be in greater concentration in Wanapitei bogs (Table 6). Sulphate and several metals (Ni, Mn, Al, Fe, Cu) were also in higher concentration in Wanapitei bog pools than at Ranger. Fen pools showed a tendency towards lower pH, higher sulphate and metals at Wanapitei relative to Ranger (Table 6). A frequency distribution of pool pHs in the two study areas (Fig. 7) shows a predominance of Wanapitei samples at the lowest pHs in both spring and summer.

Table 5: Chemistry of headwater lakes at Ranger and Wanapitei (medians for June 1983) compared to fen pool chemistry (May 1985).

	Ranger		Wanapitei	
	Lakes	Fens	Lakes	Fens
	N=69	N=8	N=55	N=8
K_{corr} (umho/cm)	22.0	20.0	25.6	25.7
Ca (mg/l)	3.07	2.20	2.79	2.41
Mg (mg/l)	0.69	0.54	0.64	0.59
Na (mg/l)	0.81	0.59	0.86	0.72
SiO_2 (mg/l)	3.24	2.56	2.87	3.72
SO_4 (mg/l)	7.27	5.16	10.9	9.18
pH	6.46	5.66	5.04	5.42
Alk. (ueq/l)	68.9	34.5	0.0	9.9
Al (ug/l)	129	114	209	129
Mn (ug/l)	10.7	14.6	60.3	47.1
Colour (hazen)	30	60	15	53
TDC (mg/l)	9.3	12.8	4.8	11.3
DOC (mg/l)	8.7	10.7	4.2	9.6
A^- (ueq/l)	79.3	88.5	38.5	78.9
DIC (mg/l)	< 1	2.0	< 1	1.6
PO_4 (ug/l)	1.19	1.25	1.14	1.42
Cu (ug/l)	1.0	< 1	1.9	1.4
Fe (ug/l)	81	95	91	235
Pb (ug/l)	< 1	< 1	< 1	< 1
Zn (ug/l)	5.2	3.9	7.7	7.0
Cl (mg/l)	0.61	0.28	0.38	0.20

Table 5 (cont.)

	Ranger		Wanapitei	
	Lakes	Fens	Lakes	Fens
K (mg/l)	0.54	0.24	0.49	0.25
Ni (ug/l)	< 1	< 1	8.4	8.5
NO_2NO_3 (ug/l)	19.4	19.2	4.7	10.0
NH_3 (ug/l)	20.4	35.4	18.0	18.5

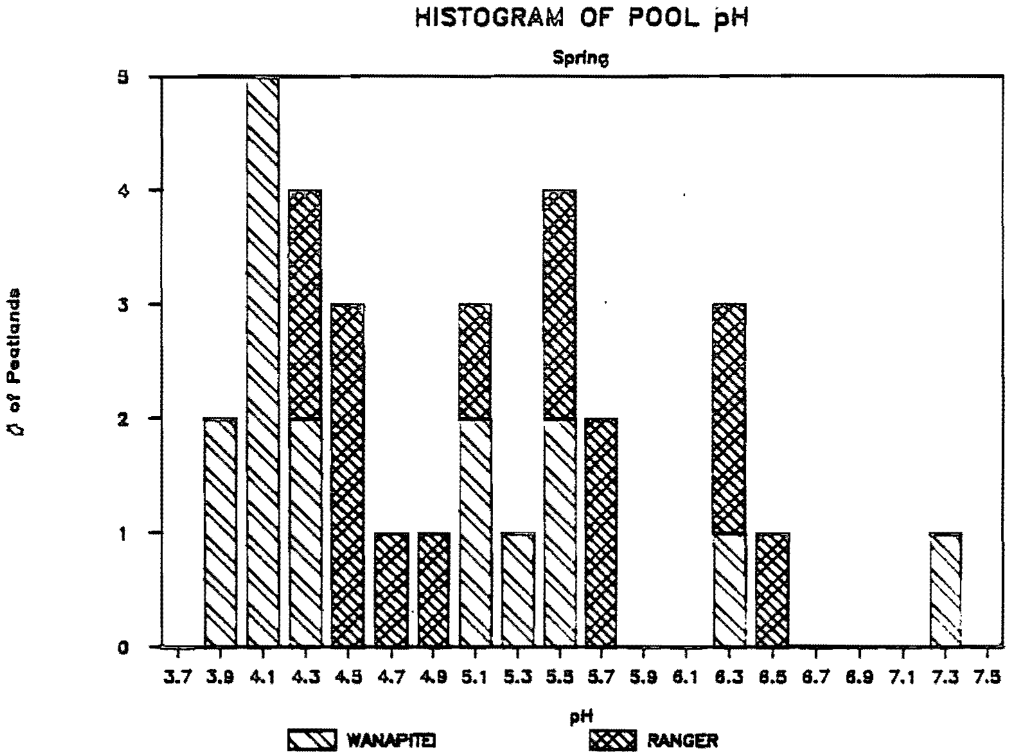
Table 6: Comparison of the chemistry of Ranger versus Wanapitei waters as measured in 1985. Values are medians. Statistical differences: * $P < 0.05$, ** $P < 0.01$, Wilcoxon tests.

	Pool Samples				Mat Samples			
	Bogs		Fens		Bogs		Fens	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
N =	7	8	8	8	7	8	8	8
Spring								
K_{corr} (umho/cm)	10.8	** 20.9	20.0	* 25.7	8.3	* 13.9	10.7	13.6
Ca (mg/l)	0.45	1.30	2.20	2.41	0.44	0.78	0.83	0.93
Mg (mg/l)	0.16	0.39	0.54	0.59	0.14	0.22	0.30	0.27
Na (mg/l)	0.35	0.51	0.59	0.72	0.33	0.44	0.46	0.62
SiO_2 (mg/l)	1.74	2.14	2.56	3.72	1.53	2.70	1.08	2.21
SO_4 (mg/l)	2.51	** 8.06	5.16	** 9.18	1.20	3.06	1.16	1.57
pH	4.45	** 4.17	5.66	5.42	4.38	** 3.98	4.73	4.49
Alk. (ueq/l)	0.0	0.0	34.5	9.9	0.0	0.0	0.0	0.0
Al (ug/l)	49	* 191	114	129	127	111	62	83
Mn (ug/l)	19.0	* 43.5	14.6	* 47.1	9.8	17.8	9.4	* 22.2
Colour (hazen)	60	70	60	53	150	150	150	150
TDC (mg/l)	13.4	15.4	12.8	11.3	24.1	34.0	23.9	33.4
DOC (mg/l)	11.9	14.0	10.7	9.6	19.6	29.0	20.5	28.5
A^- (ueq/l)	72	81	89	79	120	156	147	186
DIC (mg/l)	1.6	2.0	2.0	1.6	3.3	4.5	3.8	3.9
PO_4 (ug/l)	1.55	1.47	1.25	1.42	2.22	2.95	2.48	3.02
Cu (ug/l)	0.0	** 2.4	< 1	** 1.4	1.8	4.1	1.6	** 7.9
Fe (ug/l)	97	** 215	95	235	110	** 480	119	** 690
Pb (ug/l)	< 1	1.2	< 1	< 1	1.5	1.8	1.0	1.4
Zn (ug/l)	6.9	7.6	3.9	7.0	20.0	18.4	19.2	21.6
Cl (mg/l)	0.18	0.16	0.28	0.20	0.49	0.35	0.47	0.59
K (mg/l)	0.24	0.15	0.24	0.25	0.34	0.13	0.38	0.45

Table 6 (cont.)

	Pool Samples				Mat Samples			
	Bogs		Fens		Bogs		Fens	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
N =	7	8	8	8	7	8	8	8
Spring								
Ni (ug/l)	< 1	** 9.8	< 1	** 8.5	1.4	** 9.8	< 1	** 9.1
NO_2NO_3 (ug/l)	10.3	7.1	19.2	10.0	10.0	7.4	7.4	* 0.0
NH_3 (ug/l)	36.8	15.4	35.4	* 18.5	48.1	* 25.3	45.5	34.0
Summer								
K_{corr} (umho/cm)	5.6	13.1	20.7	21.8	10.9	17.2	17.2	17.6
Ca (mg/l)	0.50	1.34	2.78	2.24	0.75	1.44	1.20	1.31
Mg (mg/l)	0.15	0.35	0.74	0.51	0.27	0.35	0.45	0.31
Na (mg/l)	0.23	* 0.43	0.67	0.71	0.31	** 0.59	0.43	0.54
SiO_2 (mg/l)	0.03	0.42	1.87	0.89	0.83	** 1.52	1.39	1.98
SO_4 (mg/l)	2.48	* 5.92	2.94	* 6.29	2.22	6.21	3.70	4.56
pH	4.39	** 4.08	6.19	* 5.32	3.92	3.81	4.00	3.89
Alk. (ueq/l)	0.0	0.0	56.1	5.2	0.0	0.0	0.0	0.0
Colour (hazen)	65	63	100	68	280	388	280	430
TDC (mg/l)	14.3	14.2	16.0	13.1	37.6	50.7	32.5	44.3
DOC (mg/l)	13.5	12.8	14.5	11.5	35.4	47.0	31.4	41.9
A^- (ueq/l)	82	73	134	* 97	183	** 233	194	241
DIC (mg/l)	1.0	1.1	1.7	2.2	1.8	2.5	1.5	2.5
PO_4 (ug/l)	1.91	1.50	2.52	1.64	2.79	* 4.07	2.83	* 4.14
Cl (mg/l)	0.12	** 0.24	0.29	0.34	0.49	* 0.88	0.74	0.78
K (mg/l)	0.04	0.04	0.26	* 0.10	0.88	1.00	1.21	1.09
NO_2NO_3 (ug/l)	0.0	* 8.5	2.5	** 12.0	4.0	** 17.0	4.0	** 33.5
NH_3 (ug/l)	75.	** 161.	75.	** 153.	122.	** 258.	167.	** 270.

a



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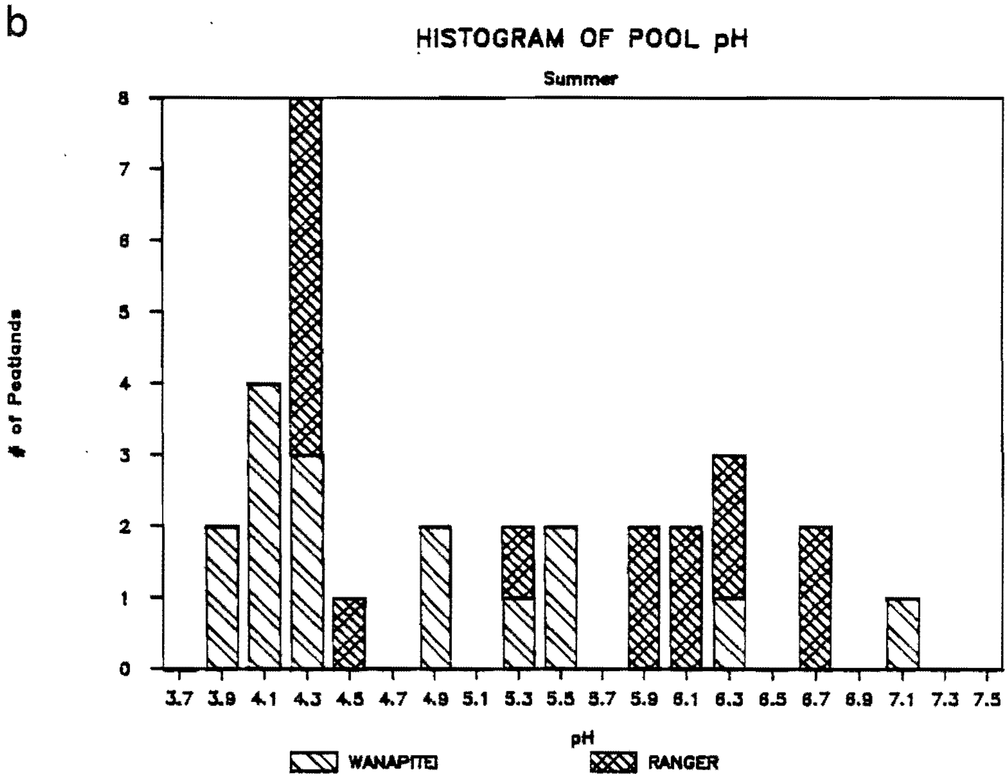


Figure 7: Frequency distribution of pool pHs in the two study areas:
(a) May 1985
(b) August 1985

Differences between mat samples at Wanapitei and Ranger were not as marked as pool differences. Spring mat samples tended to be lower in pH and higher in metals and sulphate at Wanapitei (Table 6). In the summer, Wanapitei mat samples showed a greater concentration of organics relative to Ranger.

3.3.2.5 Anionic Composition

The percentage of organic anions relative to mineral anions, particularly sulphate, can be used to shed light on the nature of the acidity in wetlands. For this purpose, we calculated the percent of total anions made up by each of: SO_4, Cl, alkalinity (HCO_3), NO_3, and organic anion (A^-). The contribution of nitrates were always less than 1% and therefore not considered below. Results are presented graphically in Figure 8. Not surprisingly, organic anions were dominant in mat samples, regardless of origin or season. Sulphate ions were next in importance in mat samples followed by chloride ions, with no alkalinity present in most samples.

Pool samples had relatively higher organics and lower sulphate in summer compared to spring, while mat samples showed the reverse trend, i.e. higher sulphate in summer samples compared to spring.

Differences between bogs and fens were not apparent in the mat samples. For the pool samples, many fens had an added alkalinity component not present in bog pools, particularly at Ranger.

Wanapitei pools showed a higher proportion of sulphate anions than pools at Ranger. This was true in both bogs and fens, in spring and summer. Sulphate ions comprised greater than 50% of anions at Wanapitei,

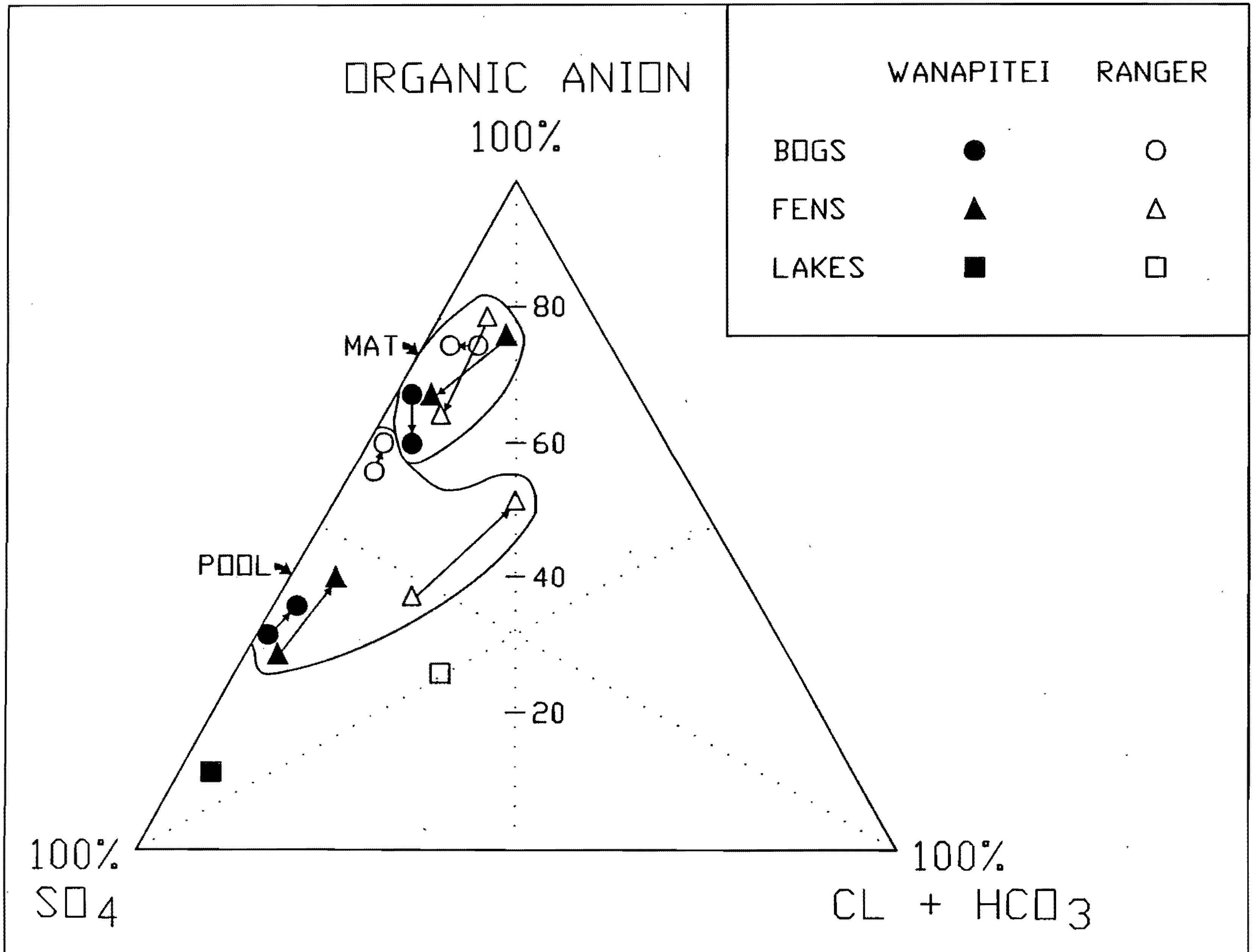


Figure 8: Anionic composition of peatland waters, illustrated graphically, using median values. Lines with arrows connect spring to summer values for the same group of peatlands. Headwater lake data from June 1983 is plotted for comparison.

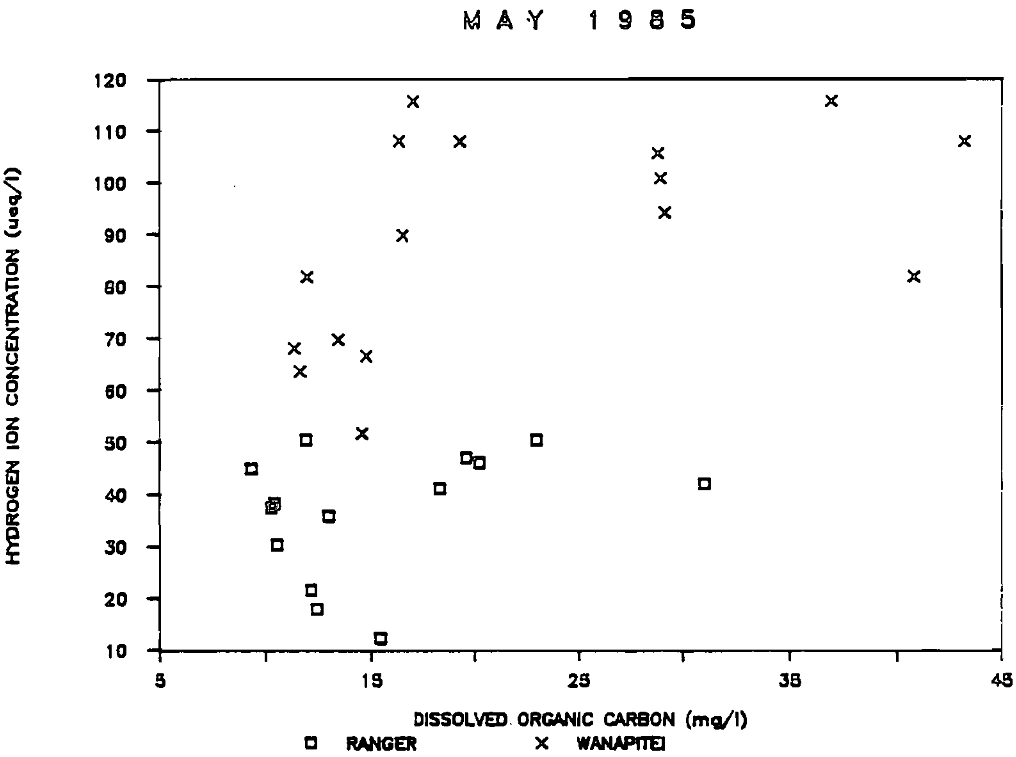
less than 50% at Ranger. These study area differences are also apparent in a comparison of headwater lakes (Fig. 8). Wetland pools are intermediate between wetland mat samples and lakes with respect to the relative contributions of organic and sulphate anions.

A second method used here for illustrating the relative importance of organic acidity in the two study areas is to examine the relationship between hydrogen ion concentration and DOC (as in Gorham et al. 1985b). For this analysis we have restricted ourselves to bogs, since they have little or no bicarbonate buffer that would obscure a relationship between H^+ and DOC.

Hydrogen ion concentrations showed a positive relationship with DOC, both in spring (Fig. 9a) and summer (Fig. 9b), primarily because of the increased organic acidity in mat samples relative to pool samples. This relationship was stronger in the summer ($R^2 = 0.54$), than in the spring ($R^2 = 0.29$). In both cases hydrogen ion was higher at Wanapitei than at Ranger for values of DOC typical of pools (10-20 mg/l).

The low proportion of variability in acidity explained by DOC (as an indicator of organic acidity), particularly in spring, plus the study area differences in this relationship, make it desirable to see if other chemical variables besides DOC can further explain the hydrogen ion concentration. Multiple regressions were therefore run against DOC, SO_4 (as an indicator of mineral acidity), and Ca (as an indicator of minerotrophic influence). The addition of these latter two variables improved the amount of explained variance in H^+ from 29.1% to 84.6% in spring samples, and from 53.5% to 81.9% in summer. In the spring, DOC and SO_4 contributed positively to acidity in approximately equal

a



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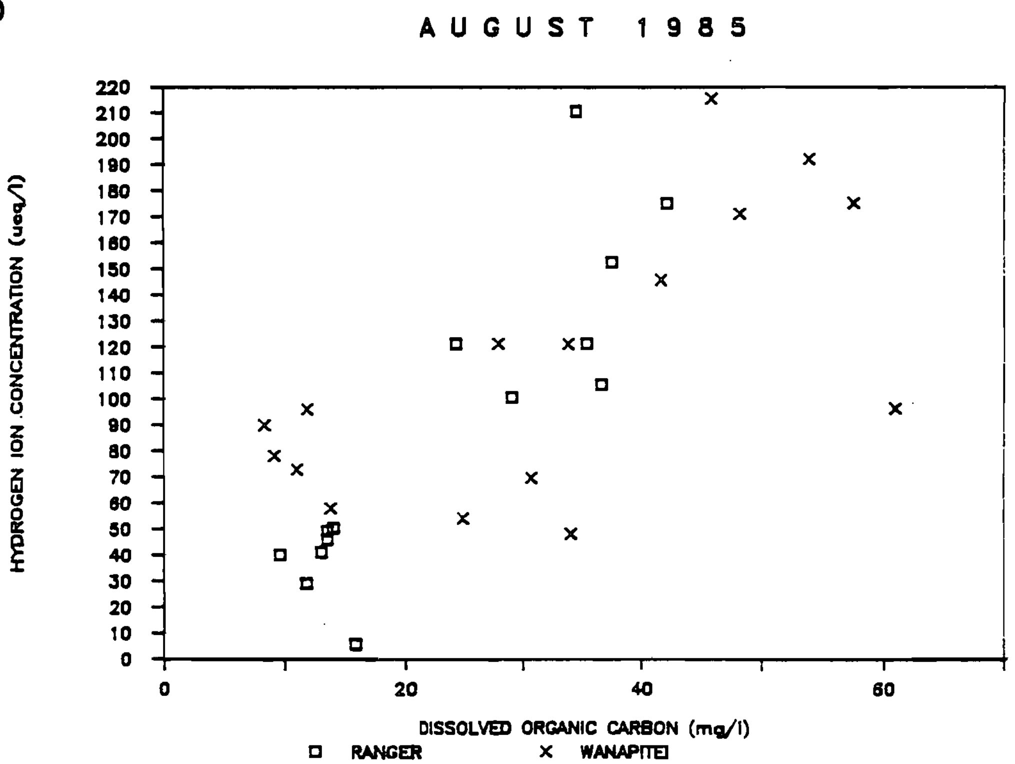


Figure 9: Relationship between hydrogen ion concentration and dissolved organic carbon concentration, showing values for both study areas: (a) spring and (b) summer.

Table 7: F-values from multiple regressions of hydrogen ion concentration against dissolved organic carbon (DOC) sulphate (SO_4) and calcium (Ca). Values of R^2 are for total amount of variation explained by the three variables.

		All Bog Samples		Bog Pools Only	
Variable	Sign	Spring	Summer	Spring	Summer
DOC	+	96.6	94.4	39.1	100.2
SO_4	+	90.9	39.2	76.4	100.6
Ca	–	38.7	32.7	44.2	71.2
R^2		0.85	0.82	0.91	0.93
N		30	30	15	15

fashion, while Ca contributed negatively to acidity (Table 7). In the summer, DOC contributed more strongly than SO_4 or Ca (Table 7) to explaining acidity. Sulphate was more important when only bog pool water was included in the analysis (Table 7). In the spring, SO_4 explained more of the variation in hydrogen concentration than either DOC or Ca, and was equally as important as DOC in summer.

3.4 DISCUSSION

The peatlands selected for study are typical of the small peat-filled depressions present in central Ontario (Monenco 1981, Zoltai and Pollett 1983), being small in area yet with a deep peat accumulation. Zoltai and Pollett (1983) gave a peat depth of 5-7 m for this type of peatland, which compares well with our range of 4-12 m. The depth and humification profiles of the peat were reasonably uniform across the two study areas and peatland types, and did not appear to be influenced by the underlying mineral material, which varied from rock to gravel, sand and clay. It is therefore very unlikely that chemical differences between the two study areas are attributable to differences in peat development.

Water levels in all wetlands showed a seasonal decline from mid-May to mid-August, illustrating the drier summer conditions in these wetlands. Continental bogs typically show a greater seasonal influence than maritime bogs (Gorham et al. 1985a) with the result that water chemistry in summer in continental bogs often shows increased ionic concentrations and reoxidized sulphur. The change in water levels did not differ appreciably between bogs and fens or between Wanapitei and

Ranger, so that this seasonal change in chemistry is unlikely to bias comparisons between these groups of peatlands.

The size of the open pools in these peatlands appeared to have some effect on water chemistry, though examination of the data showed that only a few of the smallest pools were influenced more highly by organics than the larger pools. The size of the pools in most instances (greater than 0.2 ha) appears to be large enough that the pools act almost independently of the surrounding peat mat. Sjors (1959) stated that large peatland pools in Hudson Bay lowland bogs were essentially rainwater basins, little influenced by the Sphagnum surrounding them. Vitt and Slack (1975) also showed that large chemical differences could be found in bog mats and adjacent bog lakes. Some of the larger pools in our study could be considered small bog lakes, though none of these pools exceeded 40% of the total area of the wetland.

3.4.1 Chemistry

The similarity of various physical and hydrological conditions in the two study areas allows further comparisons of water chemistry between and within these areas.

Most of the variation in chemical parameters can be divided into organic or mineral groupings. Pool and surface mat waters differ primarily in organic parameters, while pool waters of bogs and poor fens differ primarily in mineral components. Mat waters of both bogs and fens were very oligotrophic, indicating that minerotrophic influence is not necessarily present in the mat community despite mineral conditions in several fen pools.

Comparison of pool chemistry between Wanapitei and Ranger study areas indicate differences which do not readily fall into organic or mineral categories. Pool pH is lower at Wanapitei, despite higher mineral content of the water, and several metals are elevated without a change in organic content. These changes are similar to the response of headwater lakes to acid deposition (McNicol et al. 1986b) and appear to indicate a greater influence of mineral acidity at Wanapitei. This is further illustrated by the increased importance of sulphate relative to organic anions at Wanapitei compared to Ranger, and the strong influence of both sulphate and organics on the pH of bog waters. These study area differences are not as readily observed among mat samples, particularly in the summer when organic concentrations are high. However, in the spring there are small differences in bog mat chemistry which reflect the more acid conditions seen in Wanapitei pools and lakes. This could be a result of acidic snowmelt in the spring.

These results comply with recent literature on the influence of acid deposition on peatland waters. Studies dealing largely with water from within the peat mat have shown little or no influence of acid deposition on bog pH. Hemond (1980) showed that the pH of peat waters in an ombrotrophic bog in New England was controlled by organic acids. Bayley and Schindler (1985) experimentally showed that additions of mineral acid to bogs are rapidly neutralized by nitrate uptake and sulphate reduction. Studies that have dealt with surface pools of water have found an increase in sulphate and decrease in pH near industrialized areas (e.g. Gorham 1956, 1958, Van Dam et al. 1980, Vangenechten et al. 1981, Gorham et al. 1985a). These pools are apparently more susceptible to acidification because sulphate remains in an oxidized form. The levels of sulphate measured in Wanapitei pools (as high as 10 mg/l) approaches levels observed in polluted English bogs (3.6-19.2 mg/l, Gorham 1956).

Sulphate levels are high in mat water at both Wanapitei and Ranger, reaching levels of greater than 10 mg/l in summer samples at Wanapitei. Median levels of 6.2 mg/l at Wanapitei and 2.2 mg/l at Ranger are substantially higher than bog surface waters measured by Gorham et al. (1985a) in a transect of eastern North America (mean of 0.86 mg/l), or by Vitt and Bayley (1984) in northwestern Ontario (0.74 mg/l in a surface pool). The reason for the high sulphate levels in peatland surface water at Ranger is unknown.

In conclusion, organic acidity is obviously important in peatland waters, yet mineral acidity appears to play an increased role in the geochemistry of Wanapitei peatlands, likely due to increased acid deposition. Chemical effects are noticeable primarily in pool waters, yet may also be affecting surface waters on the mat. Pool waters can be viewed as an extension of the lake ecosystem into more organic waters, with fen pools being similar in mineral chemistry to lake waters. Since pool waters appear to be undergoing the largest change from Wanapitei to Ranger, effects on wildlife should be most noticeable for aquatic species or those that rely on the pool for prey. Integration of wildlife studies from headwater lakes and wetland pools should be productive.

4. VEGETATION OF THE PEATLANDS

4.1 INTRODUCTION

Investigation into the vegetational composition of the study peatlands is important for a number of reasons. Vegetational analysis provides a detailed description of the peatlands, and therefore allows comparisons with peatlands studied elsewhere in North America. Vegetation provides habitat for peatland-dwelling wildlife and food for many of these animals, so it is profitable to quantify the types of habitat present. Third, many plant species are sensitive indicators of physical and chemical conditions in wetlands (Sparling 1973, Glaser et al. 1981). Their presence can be used as an accurate measure of pH in a peatland habitat (e.g. Gorham et al. 1985b). Finally, severe anthropogenic acid deposition is known to change the vegetational composition of bogs (Tallis 1964, Ferguson and Lee 1983) and can reduce the growth of *Sphagnum* at lower levels of acid deposition (Lee et al. 1985). It is possible that vegetational differences may be noticeable among peatlands subjected to different levels of acid deposition.

The purpose of this investigation is to provide a preliminary analysis of peatland vegetation at Wanapitei and Ranger. This will provide information on plant-chemical interrelationships, and allow crude comparisons between the two study areas and with peatlands in other areas of eastern North America. The emphasis here is on vascular plants, with little species identification of mosses or lichens.

4.2 METHODS

Thirty-one peatlands (16 at Wanapitei, 15 at Ranger) were visited 5 to 7 times each between early May and the beginning of August. On each visit, flowering vascular plants were noted, with unknown species being collected for later identification.

During August and early September, the vegetation of each peatland was sampled quantitatively using methods similar to those presented by Vitt and Slack (1975) and Vitt and Bayley (1984). Major vegetational stands were delineated within which plant composition appeared to be relatively uniform (e.g. pool edge, shrub mat, sedge mat, treed zones), usually three stands per peatland (Note: we did not attempt to quantify aquatic vegetation within the pools). Within each stand 5 to 10 1-m^2 quadrats (number depending on size of the stand) were placed at regular paced intervals and percent cover of each vascular plant species was estimated. Cover of easily identifiable groups of mosses and lichens was also estimated. Plant names for vascular plants are from Fernald (1970).

Prominence values (PV) were calculated for each species in each stand as an index of abundance (from Vitt and Bayley 1984):

$$PV = C \times F^{1/2}$$

where C is mean percent cover and F is frequency of occurrence in a stand. These prominence values were used in a detrended correspondence analysis (DECORANA, Hill 1979) to provide an ordination of the stands. Plant taxa which occurred in less than 5 of the 95 stands were not included in the ordination. Results of the ordination were used to visually divide the stands into 4 groups based on the abundances of common bog plants. Within each group, average prominence values of each plant species were calculated for each of the two study areas.

Chemical values presented are from the summer (August) sampling period discussed earlier, with additional field pHs for some stands with no lab chemistry. Chemical analyses were not available for several stands, particularly the drier sites where surface water was not present in the summer.

The index of shade presented is the sum of prominence values of tree species for each stand, as in Vitt and Slack (1975).

4.3 RESULTS

Ninety-five stands of vegetation were sampled in total, 48 at Ranger peatlands and 47 at Wanapitei. Examination of the two-dimensional ordination of these stands (Figure 10) shows that high values of shade are clustered at the high end (right) of axis 1, while pool edge stands tend to be to the left. This appears to indicate that the relative dryness of the stands, ranging from wet pool edge to densely treed stands, was a major component of variation.

A second major component of variation is related to the degree of minerotrophy or acidity of the stand. Stands towards the top left of the ordination, i.e. high on axis 2 and low on axis 1, tend to have high pH (Fig. 11) and high calcium levels (Fig. 12) compared to stands lower on axis 2 and higher on axis 1. This minerotrophic component effectively splits most stands taken from peatlands with pool inflows and outflows

Figure 10: Ordination of peatland plant stands showing pool edge stands (boxes) and shade index for each stand (dots, see methods for calculation of shade index). Pluses without boxes are stands not at the pool edge and without trees. Size of dot indicates the magnitude of the shade index:

● small dots - shade index 1-19

● intermediate dots - shade index 20-39

● large dots - shade index 40-60

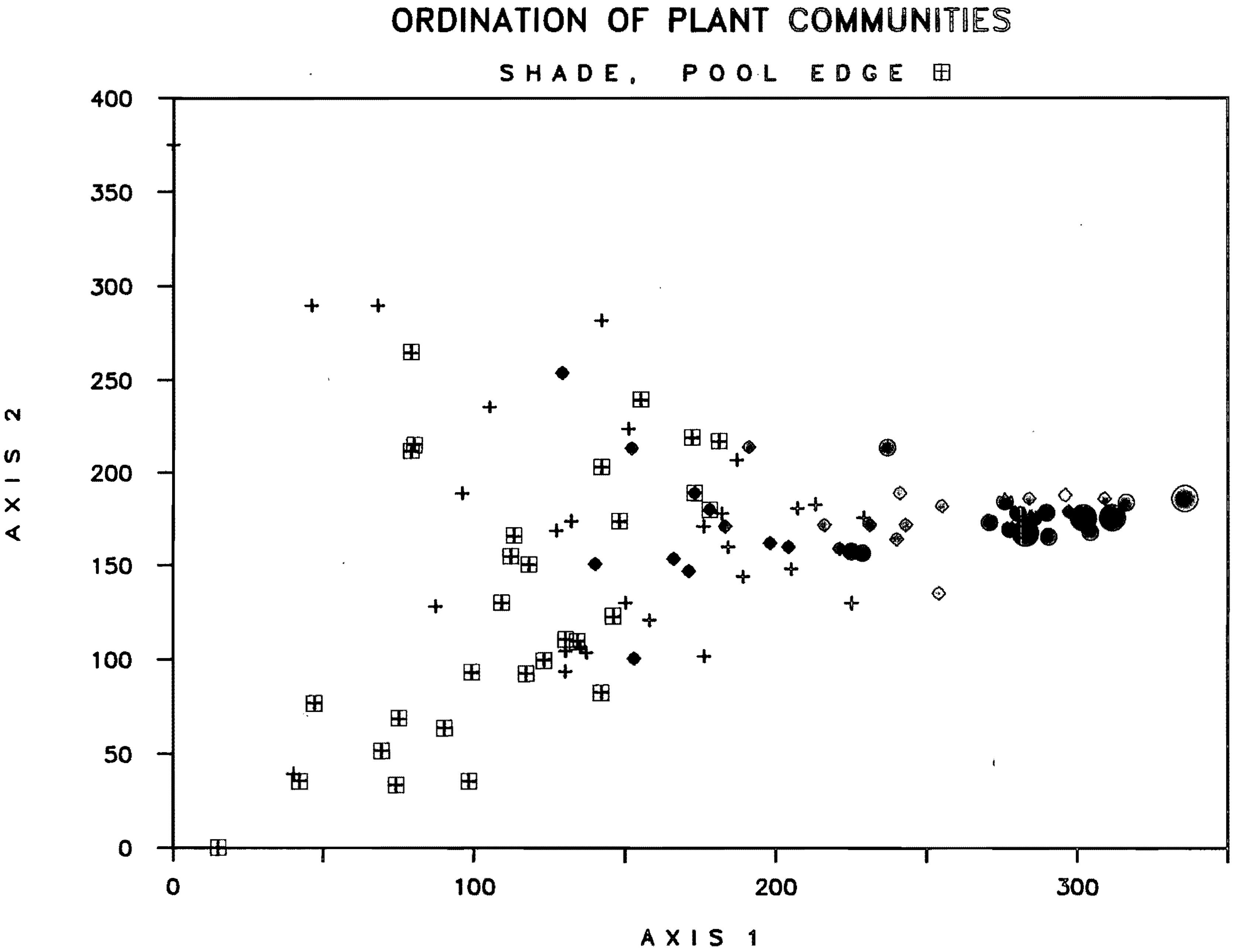

ORDINATION OF PLANT COMMUNITIES
SHADE, POOL EDGE
AXIS 2
AXIS 1
0
50
100
150
200
250
300
350
400

Figure 11: Plot of pH distribution with respect to plant stand ordination. Size of circle indicates pH class:

⊕ open circle - pH 3.7-3.9

● small dots - pH 4.0-4.4

● intermediate dots - pH 4.5-5.4

● large dots - pH 5.5-7.1

Pluses without circles indicate stands without chemistry.

p H

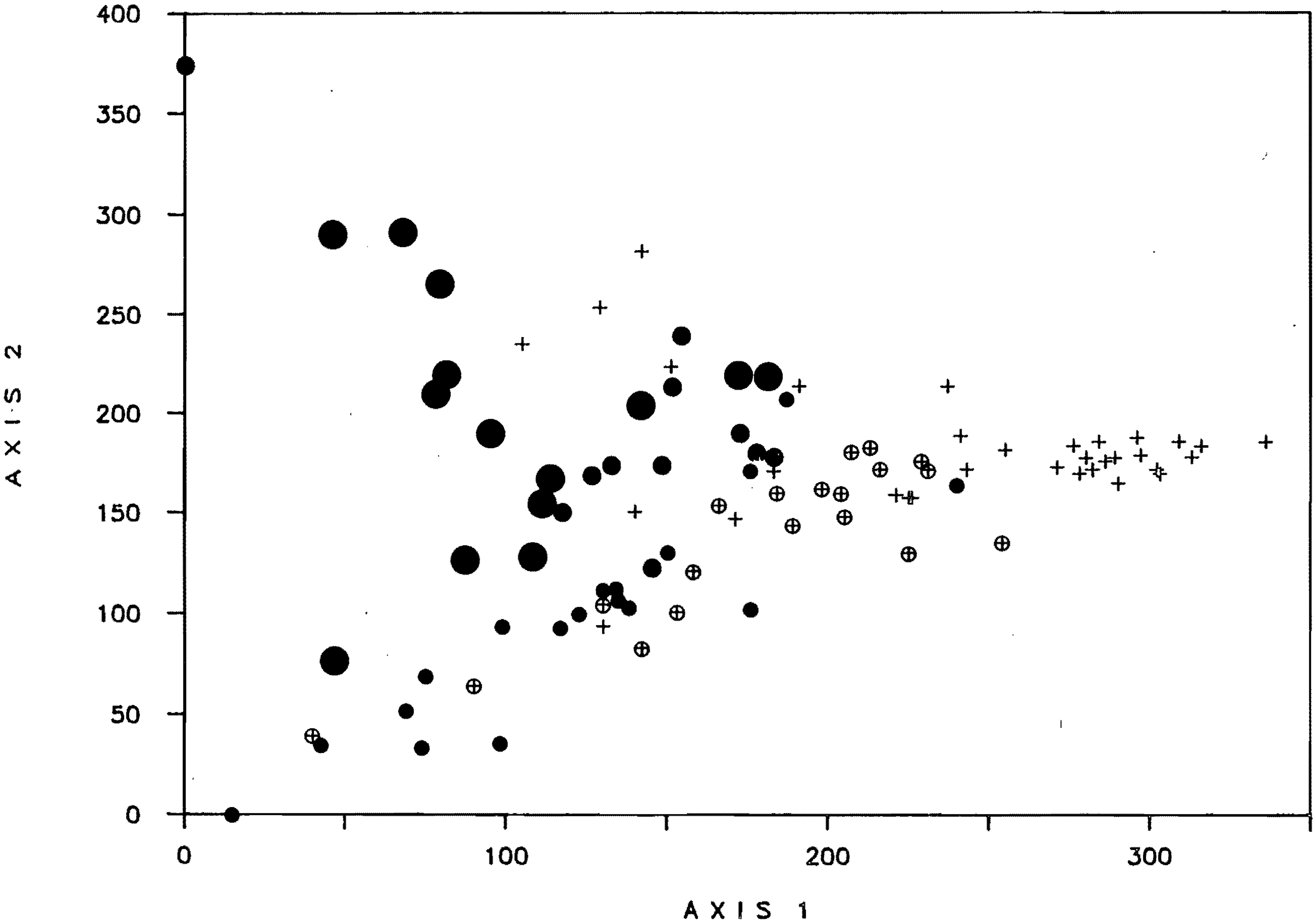


Figure 12: Plot of calcium concentration on the ordinated plant stands.

Calcium ranges are as follows:

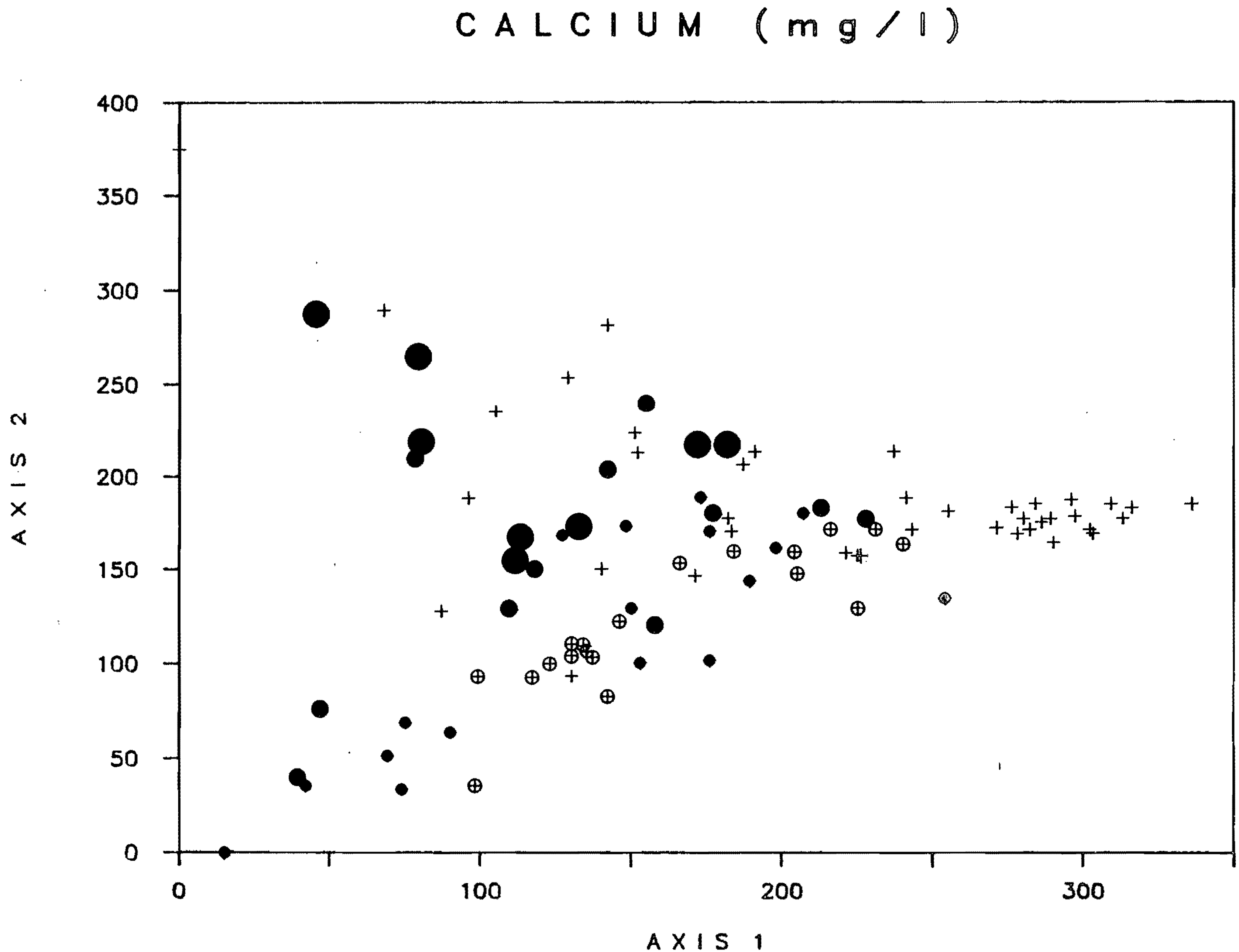
⊕ open circles - 0.3–0.9 mg/l

● small dots - 1.0–2.0 mg/l

● intermediate dots - 2.1–3.0 mg/l

● large dots - 3.6–8.9 mg/l

Pluses indicate stands without calcium values.


CALCIUM (mg/l)
400
350
300
250
200
150
100
50
0
AXIS 2
0
100
200
300
AXIS 1

(fens) from the hydrologically isolated bogs (Fig. 13). Fen vegetation dominates the upper left of the ordination while bog vegetation lies closer to the lower right of the figure. Overlap of the two groups occurs primarily in the drier stands.

In order to examine the relationship of plant species to the ordination, the stands have been divided into four groups based on the two major axes of vegetation (Fig. 14). The wet end of axis 1 (far left) has been split into a minerotrophic group (high on axis 2) and an oligotrophic group (low on axis 2). The remaining stands are split into a group dominated by shrubs (centre of the ordination) and a group dominated by trees (far right on axis 1). Mean prominence values for plant taxa in each group are presented in Table 8, and discussed below.

4.3.1 Wet Minerotrophic Community

The median pH of stands in the wet minerotrophic group was 6.10 at Ranger and 5.50 at Wanapitei, with calcium medians of 2.95 mg/l and 3.85 mg/l respectively. These minerotrophic conditions are characterized by the sedges *Carex lasiocarpa* and *C. Pseudo-Cyperus*, and the shrub *Myrica gale*. Other species which are most abundant in this group include *Utricularia vulgaris*, *Menyanthes trifoliata*, *Aster nemoralis*, *Hypericum virginicum*, and *Carex aquatilis*, the latter abundant only at Wanapitei. Despite similarities in water chemistry, the Wanapitei stands in this group differ from the Ranger stands in having a much lower abundance of the two sedges *C. lasiocarpa* and *C. pseudoCyperus*.

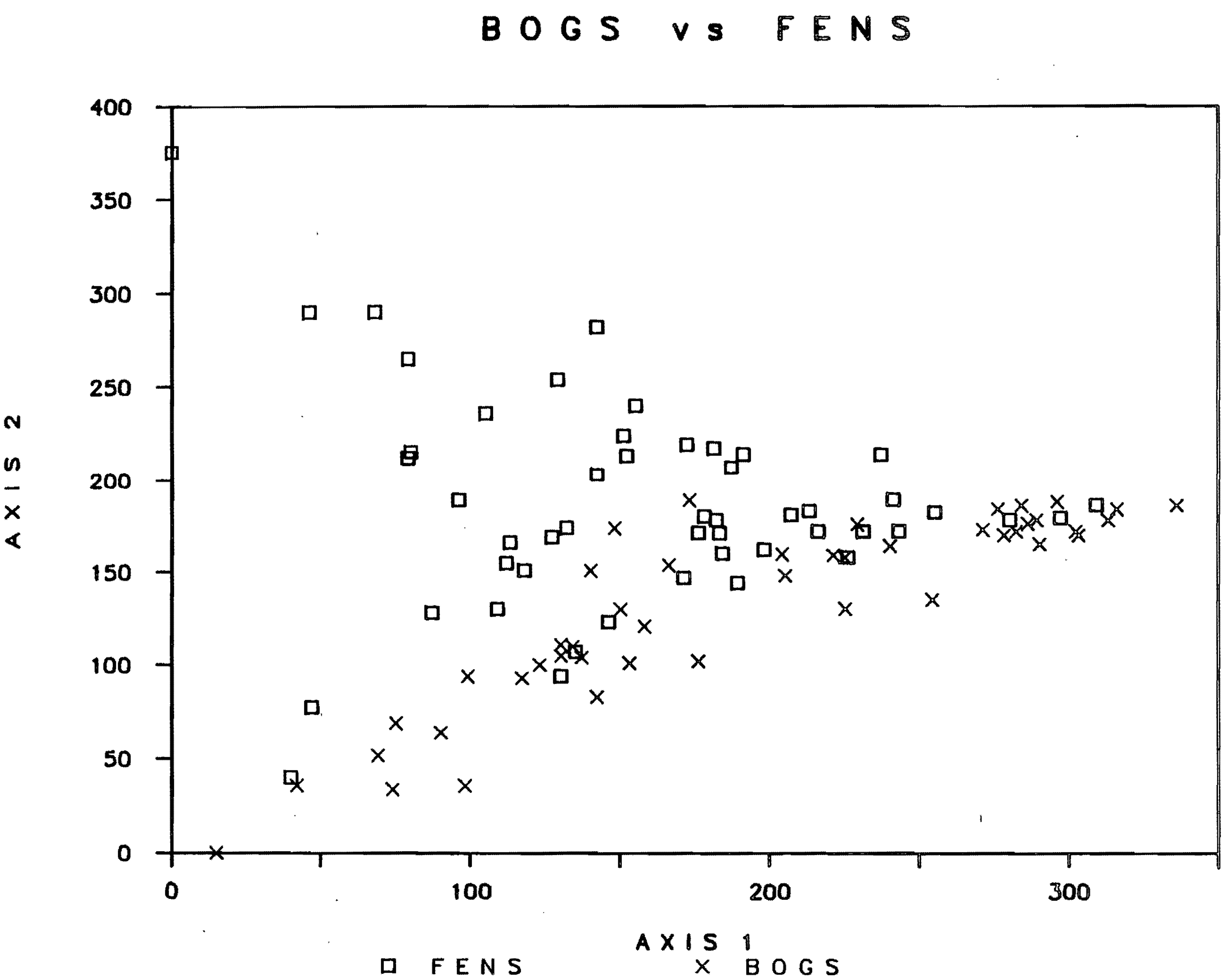


Figure 13: Distribution of ordinated plant stands from bogs vs fens.

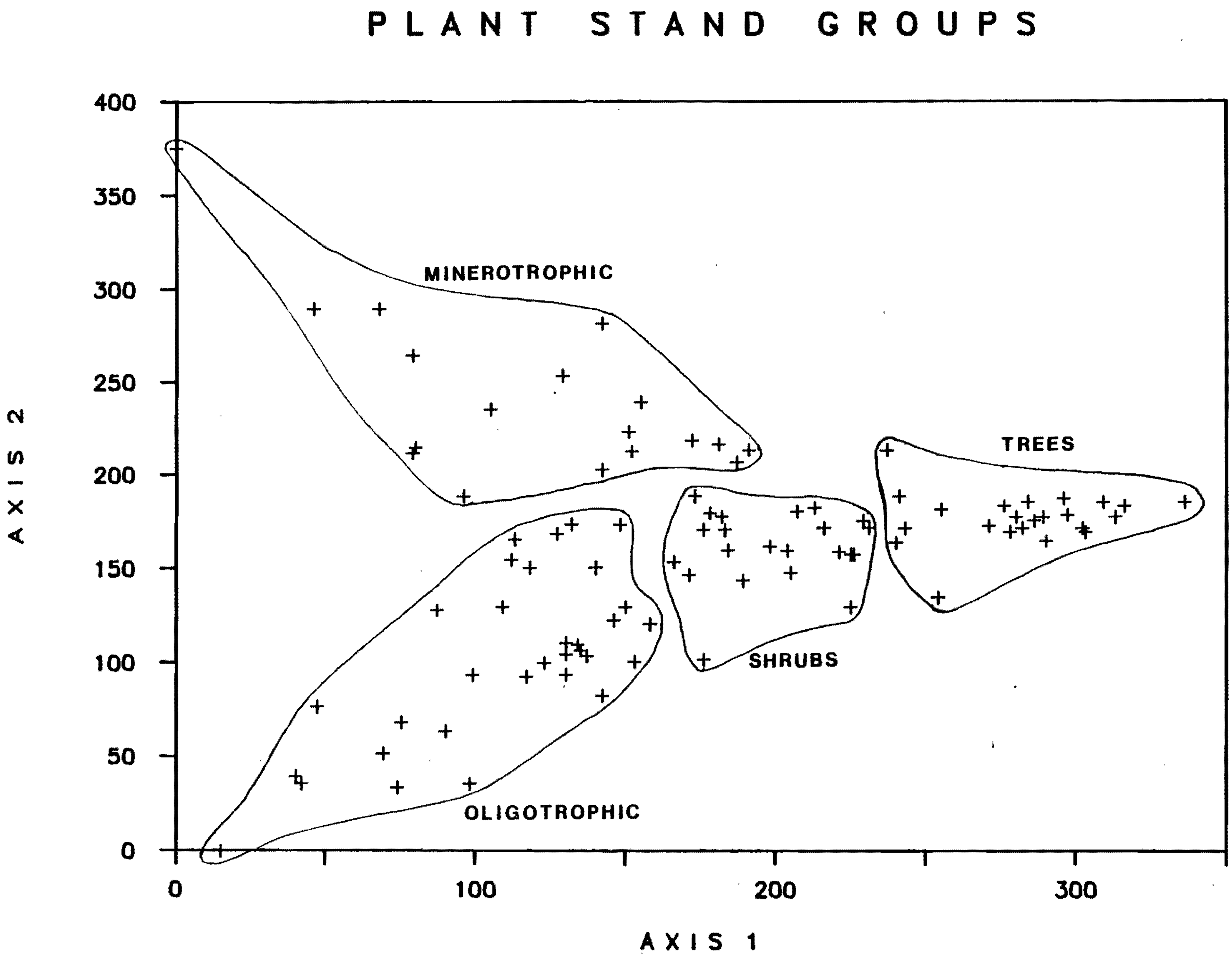


Figure 14: Artificial groupings of plant stands for purposes of further describing vegetation. Titles for each group describe a general feature of the group.

4.3.2 Wet Oligotrophic Community

The median pH of the wet oligotrophic group was 4.35 at Ranger and 4.10 at Wanapitei. Calcium medians were 0.95 and 1.50 mg/l in the two study areas. Although these medians are substantially lower than for the minerotrophic group, there is a wide range of chemical conditions in this group, with pH ranging from 3.7 to 6.7 and calcium concentrations of 0.3 to 5.2 mg/l. The sedges *Carex limosa* and *Rhynchospora alba*, as well as the yellow-eyed grass *Xyris torta* are characteristic of this assemblage. The two species of cranberry, *Vaccinium macrocarpon* and *V. Oxycoccos*, both sundews *Drosera intermedia* and *D. rotundifolia*, and *Utricularia cornuta* are also most abundant in this group. Liverwort and *Drepanocladus* moss are encountered most frequently in this group, particularly in the more acid pool edge zones, and therefore more so at Wanapitei than Ranger. There is little similarity between this assemblage of species and the minerotrophic group, despite the moist nature of both habitats. Only species with broad tolerance ranges, such as the shrubs *Chamaedaphne calyculata* (leatherleaf) and *Andromeda glaucophylla* are about equally abundant in both habitats.

4.3.3 Shrub Mat Community

The shrub mat community has a more nearly ombrotrophic nature than either of the preceding groups, with Ranger and Wanapitei stands having median pH's of 3.95 and 3.90, and calcium levels of 0.90 and 1.30 mg/l, respectively. Leatherleaf is the most common vascular plant, particularly at Wanapitei where its average prominence value is 62.5 (44.3 at Ranger). *Carex oligosperma* and *C. pauciflora* are the

Table 8: Average prominence values of plant taxa in each of four groups outlined in Figure 14, with pH and calcium values for the groups. Non-vascular plants not identified to species are in parentheses. Positive signs (+) indicate presence at PV < 0.1.

	Minerotrophic		Oligotrophic		Shrubs		Trees	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
Utricularia vulgaris	1.0	0.9	0.1	+		-		
Carex lasiocarpa	23.7	2.2	0.7	0.1	0.2			0.1
Carex Pseudo-Cyperus	28.1	9.5	0.1	1.2	0.9	0.1	1.0	+
Viola sp.	0.1	0.2					0.1	
Menyanthes trifoliata	1.3	+	0.4		0.2			
Aster nemoralis	0.3	5.0			0.1		+	0.1
Glyceria canadensis	0.5	1.1		0.4				
Myrica gale	33.7	34.8	10.9	2.1	9.5	0.9	5.6	1.4
Hypericum virginicum	+	5.0		0.4	+	+		+
Juncus sp.	0.9	+	0.1	0.5				
Carex aquatilis		9.7		4.3	0.4	1.9		0.2
Nymphaea odorata	0.4	0.3	0.8	0.1				
Pogonia ophioglossoides	0.1	+	0.3	+	+			
Thuja occidentalis		0.4					0.1	
Drosera intermedia	2.4	0.4	2.9	5.4	0.1			
Drosera rotundifolia	2.5	1.1	5.5	5.0	1.5	0.6	0.1	0.1
Carex limosa	1.5	1.8	8.7	11.8	0.5	0.1	0.5	
Utricularia cornuta	0.2		0.9	0.6	+			
Rhynchospora alba	5.7	1.5	32.7	25.0	1.9	3.5		+
Andromeda glaucophylla	6.5	0.3	6.9	0.5	6.7	0.2	3.4	0.2
(Liverwort)	3.7		11.8	14.0	1.4	2.6		
Vaccinium macrocarpon		0.1	5.1	0.6	+		0.6	
(*Drepanocladus* moss)			0.5	4.7	+			

Table 8 (cont.)

	Minerotrophic		Oligotrophic		Shrubs		Trees	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
Smilacina trifolia	+		0.2	0.1	1.5		8.0	1.4
(fruticose lichens)	+	+			+	0.3	0.2	0.9
Picea mariana		0.5	0.3	0.1	4.3	1.3	30.8	19.2
Ledum groenlandicum	0.6	0.8	0.2	0.1	3.2	0.8	35.1	19.3
Carex trisperma	0.6	0.3			0.9	5.9	18.7	9.3
Vaccinium angustifolium		0.1		+	0.2	0.2	8.1	1.5
Vaccinium myrtilloides	+					+	0.3	0.1
(Dicranum moss)		0.1		+		0.1	0.5	1.4
Nemopanthus mucronata		0.1		+			0.6	0.6
Pleurozium schreberi		+				+	2.2	1.9
Gaultheria hispidula	+				0.3		14.5	+
Cornus canadensis							0.8	+
Coptis groenlandica							0.4	+
number of stands	9	9	16	16	14	8	9	14
number of quadrats	45	47	80	79	77	50	85	125
pH - median	6.10	5.50	4.35	4.10	3.95	3.90		4.05
- minimum	4.8	4.2	3.8	3.7	3.7	3.7		3.8
- maximum	6.4	7.1	6.7	5.5	5.9	4.2		4.3
- N	7	6	16	14	10	7	0	2
Calcium - median	2.95	3.85	0.95	1.50	0.90	1.30		1.10
- minimum	2.1	2.3	0.3	0.5	0.6	0.7		0.6
- maximum	3.7	8.9	4.9	5.2	2.1	3.0		1.6
- N	4	4	16	13	9	7	0	2

Table 8 (cont.)

	Minerotrophic		Oligotrophic		Shrubs		Trees	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
Xyris torta	+		2.3	0.8	0.2			
Vaccinium Oxycoccos	4.7	4.1	14.4	19.5	10.4	14.8	6.3	2.4
Carex paupercula	1.4	1.2	0.3	0.3	1.4	1.2	0.9	0.2
Sarracenia purpurea	1.7	0.1	2.1	0.8	3.1	0.4	1.0	0.3
(Mushroom)	0.2	+	0.1	0.1	0.2	0.1	0.1	+
Acer rubrum		+	+		+		+	
Eriophorum virginicum	0.3	0.1	4.5	0.1	3.8	1.3	0.2	0.4
Eriophorum spissum		+	0.1		+		0.1	0.1
Carex oligosperma	3.0	0.2	7.8	3.7	25.3	11.2	4.9	1.9
Kalmia polifolia	1.5	1.0	5.1	5.6	8.3	8.3	4.0	4.7
(unidentified moss)	0.4	1.7	2.7	4.8	0.6	14.2	0.6	9.9
(Sphagnum spp.)	56.8	57.6	66.3	45.8	89.2	67.7	85.1	50.4
Carex pauciflora			2.2		11.1		6.2	
Chamaedaphne calyculata	17.3	30.3	15.1	23.6	44.3	62.5	28.6	51.5
Alnus rugosa	0.1	0.5	0.1		0.1	+	0.7	0.1
(unidentified moss)		3.9				0.3	0.1	1.8
Melampyrum lineare	1.4	1.2	0.3	0.3	1.4	1.2	0.9	0.2
Larix laricina		0.6	+	0.1	1.4	0.1	3.3	1.6
(Cladina lichen)	+		0.1		0.1		0.3	0.1
Kalmia angustifolia		3.9		0.7		4.1	0.3	15.9
Pinus strobus	0.1			+		0.1	0.1	0.6
Abies balsamea	+						0.1	+
(crustose lichens)	1.2	0.4	0.1	0.1	1.3	7.6	10.5	9.9
Lycopodium annotinum		+		+	0.3	0.1	0.7	0.6

characteristic sedges of this group, with the shrub Kalmia polifolia reaching its highest abundance here. The prominence value of Sphagnum is highest here also, averaging 89.2 at Ranger. Sphagnum cover is not as high at Wanapitei (67.7), but non-Sphagnum mosses are more abundant at Wanapitei than Ranger. This assemblage shares some of its more common species with the two previous wetter groups. The sedge C. paupercula is found in equal abundance here and in the wet minerotrophic group. Pitcher plants (Sarracenia purpurea) and the cotton grass Eriophorum virginicum are present about equally in the shrub mat and wet oligotrophic communities. The small cranberry (V. Oxycoccos) is almost as abundant in the shrub mat as in the wet oligotrophic group. Thus there is no distinct break between these community types.

4.3.4 Tree Community

Only two stands were sampled for water chemistry, both at Wanapitei. They indicated both low pH (median of 4.05) and low calcium conditions (median of 1.10 mg/l). A large number of plants reached peak abundance in this group, many of which are more abundant in surrounding non-peatland forest areas (e.g. Kalmia angustifolia, Lycopodium annotinum, Vaccinium angustifolium, Cornus canadensis). Typical species of the group include black spruce, Ledum groenlandicum (Labrador tea), Smilacina trifolia, and the sedge Carex trisperma. Sphagnum is still the dominant moss type, particularly at Ranger, while leatherleaf is abundant, particularly at Wanapitei.

The sedges are often used as indicators of physical conditions in peatlands, because many are specialized to rather narrow ranges of moisture, shade and minerotrophy. Distributions of the most abundant sedges encountered in this study are plotted in Figure 15. These sedges span the entire range of conditions present. Thus the minerotrophic gradient can be represented by the following sequence of sedges, from richest to poorest: C. lasiocarpa, C. Pseudo-Cyperus, C. aquatilis, and C. oligosperma (Fig. 15). The gradient from pool edge to treed stands (moisture/shade gradient) in bogs can similarly be represented as follows: Rhynchospora alba, C. limosa, C. oligosperma, C. pauciflora, and C. trisperma. In fens this gradient is represented by: C. lasiocarpa, C. Pseudo-Cyperus, C. aquatilis, C. oligosperma, and C. trisperma. Note that both fen and bog have similar plant indicators at the dry end of the spectrum.

Overall, the two study areas show very similar vegetational composition. However, two general trends are apparent from the comparison presented in Table 9. First, the ratio of Sphagnum to other types of moss is lower at Wanapitei than at Ranger, particularly in the drier habitats. Second, the total abundance of sedges in each habitat is lower at Wanapitei than at Ranger. This is especially true in the wet minerotrophic habitat group.

4.4 DISCUSSION

Studies of peatland vegetation have shown that three major physical gradients control the type of vegetation present at a site: moisture (or height above groundwater), shade, and degree of minerotrophy (Vitt and Slack 1975, 1984; Vitt and Bayley 1984). The present study is no exception to this, with a moisture/shade gradient accounting for one major axis of variation, and minerotrophy providing a second axis.

Figure 15 (a-h): Distributions of the eight most abundant sedges in the peatlands, shown against the plant ordination. For all figures the following classes apply:

○ open circles - prominence value (PV) < 1

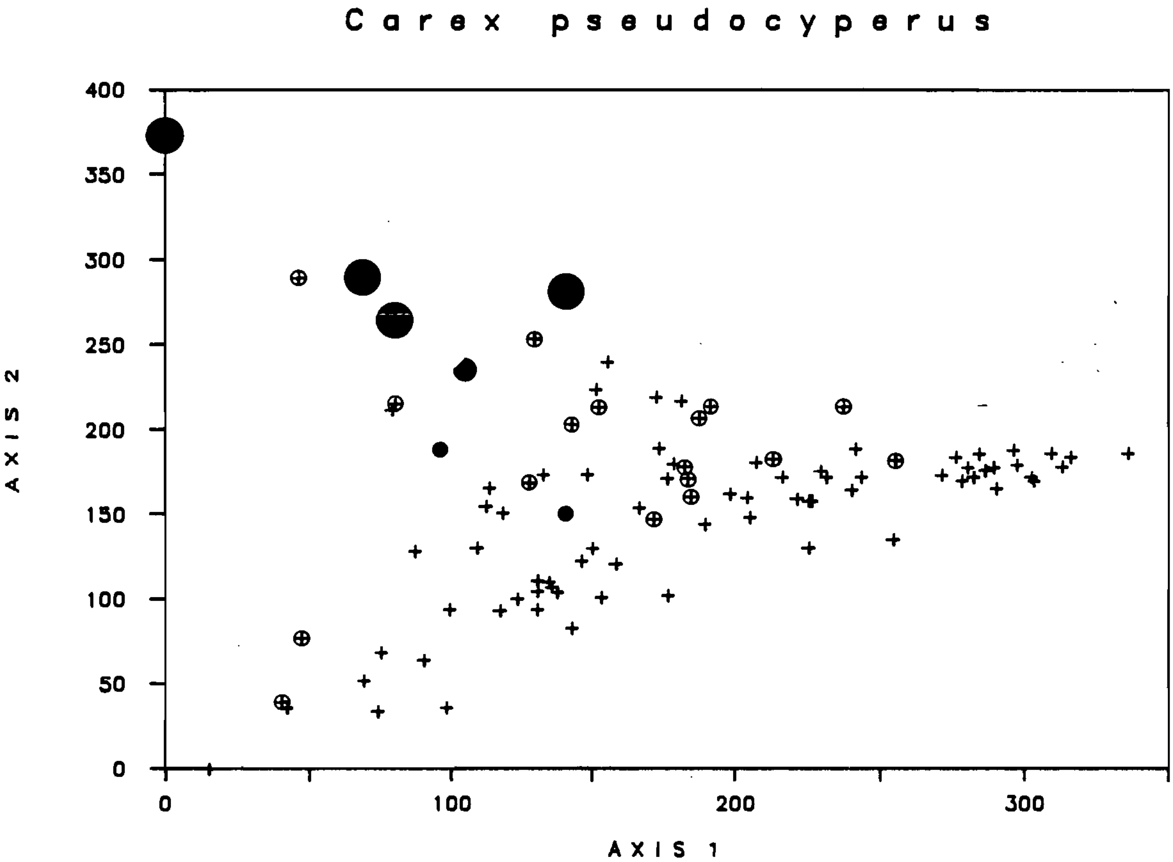
● small dots - PV of 1-20

● intermediate dots - PV of 20-40

● large dots - PV of 40-80

Pluses without circles indicate absence of the sedge.

a


Carex pseudocyperus
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AXIS 1
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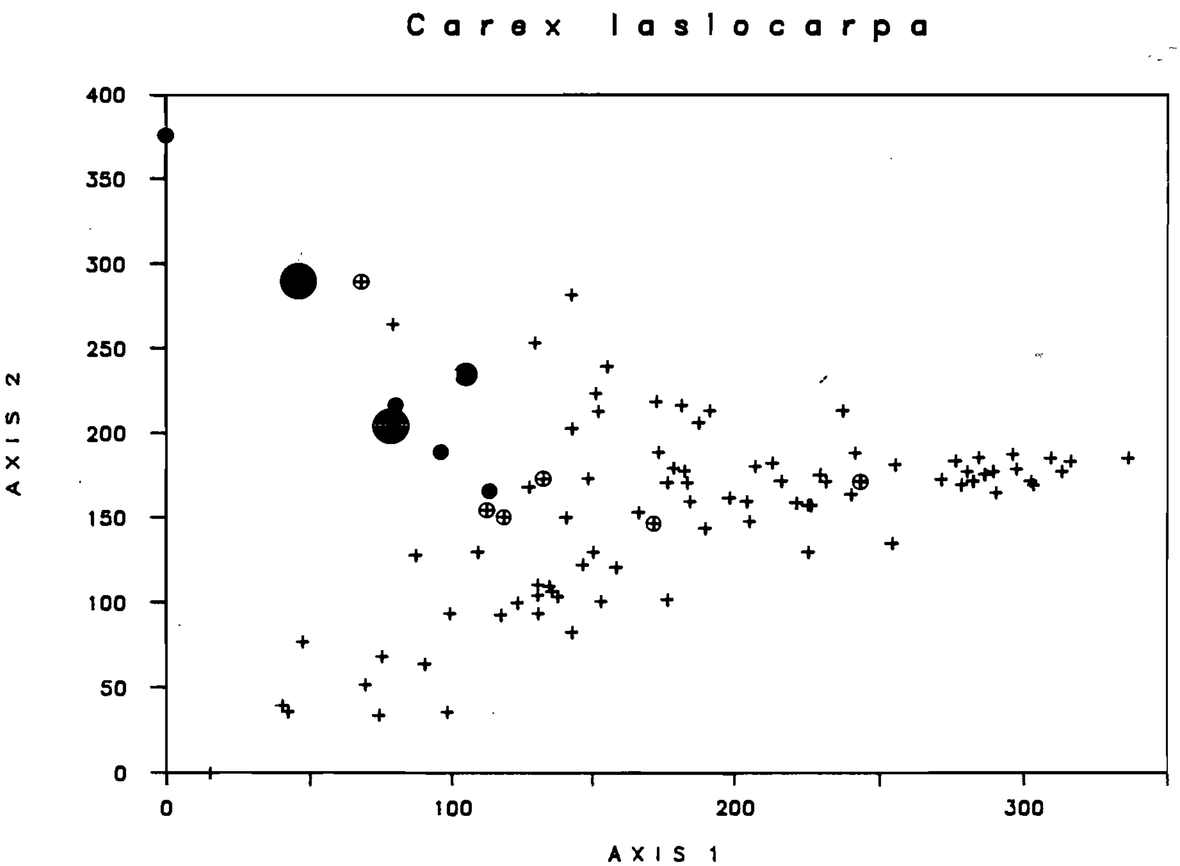
350
300
250
200
150
100
50
0
0
100
200
300

b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AXIS 1
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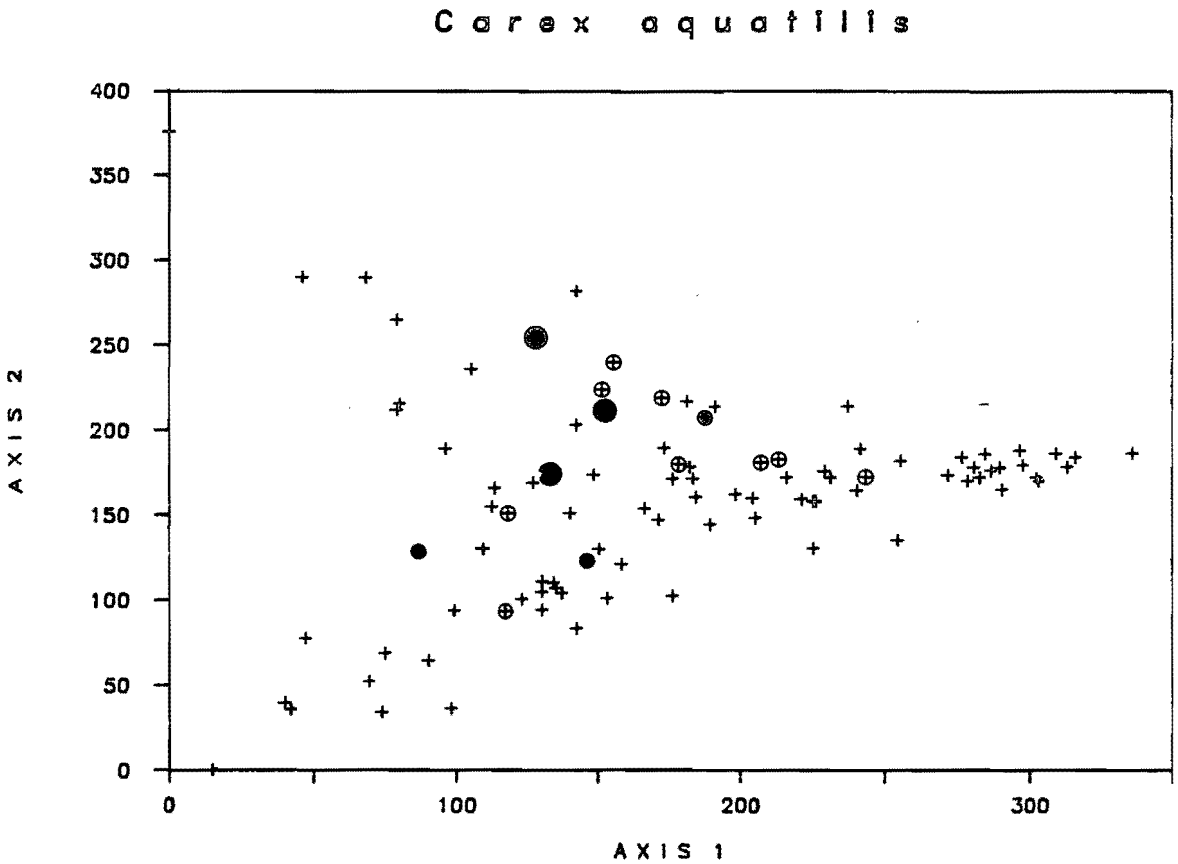
150
100
50
0
0
100
200
300

c


Carex aquatilis
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300
250
200
150
100
50
0
AXIS 2
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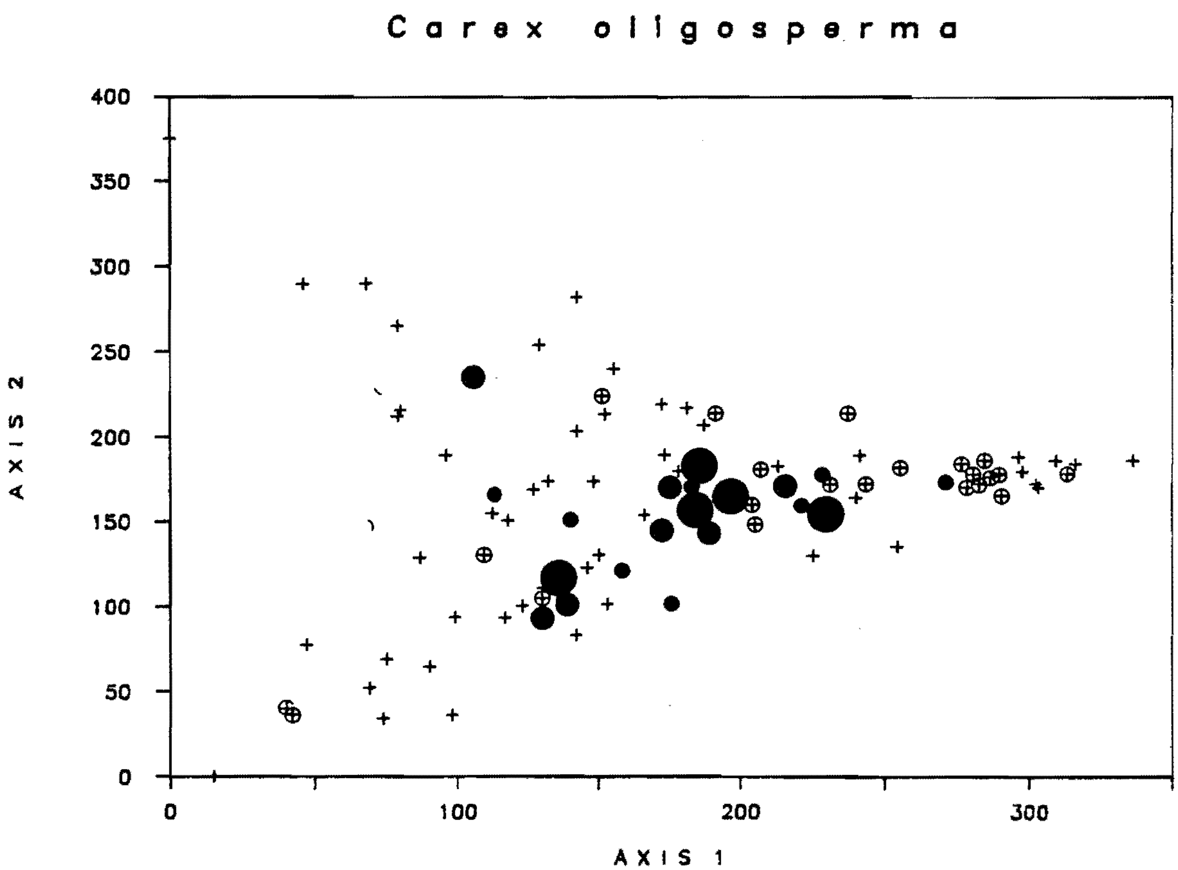
100
200
300
AXIS 1

d


Carex oligosperma
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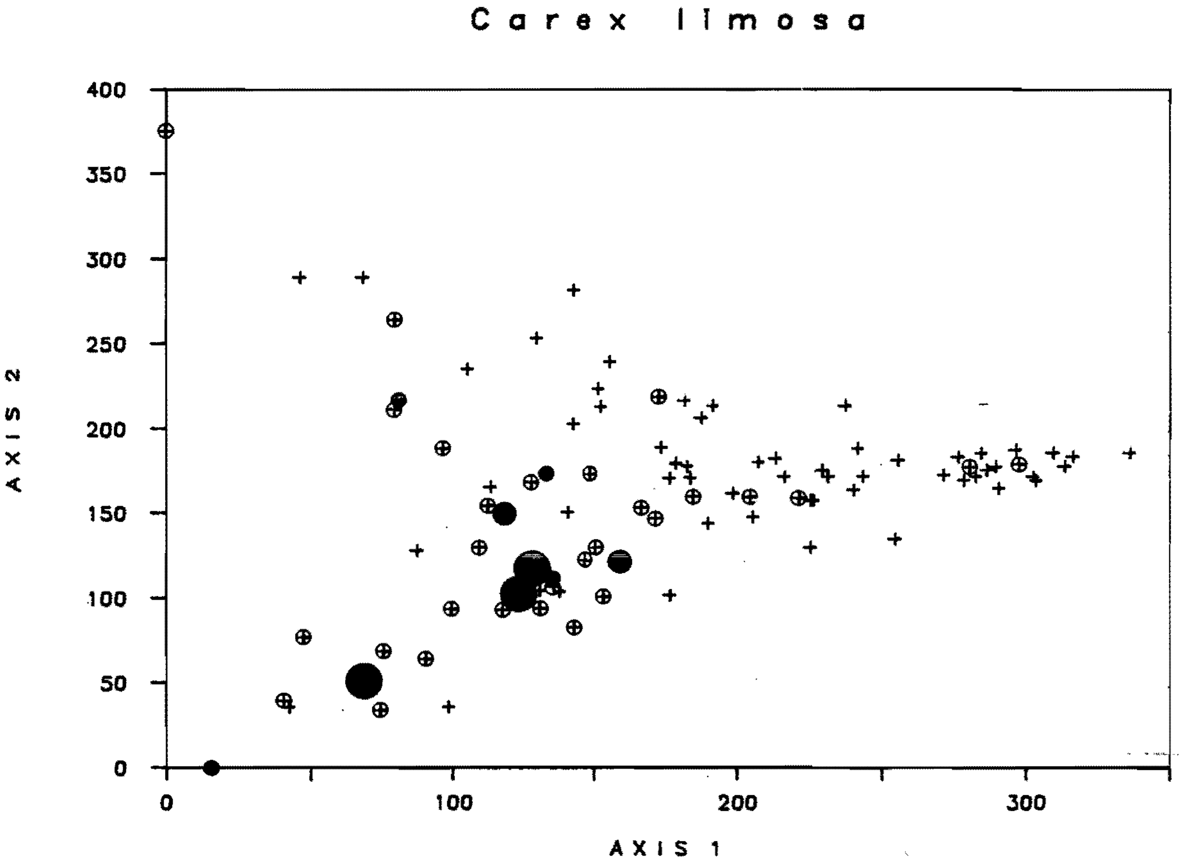
300
250
200
150
100
50
0
AXIS 2
0
100
200
300
AXIS 1

e


Carex limosa
AXIS 2
AXIS 1
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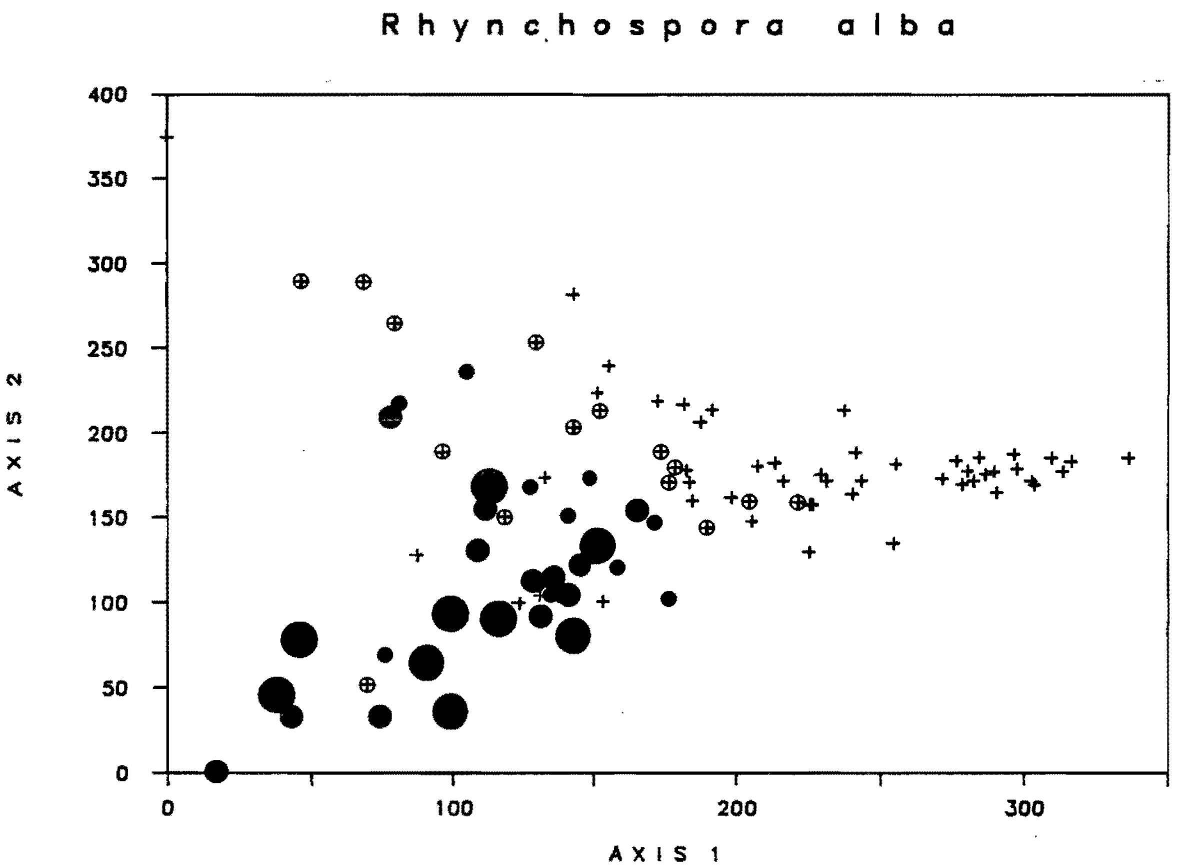
300
250
200
150
100
50
0
0
100
200
300

f


Rhynchospora alba
AXIS 2
AXIS 1
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250
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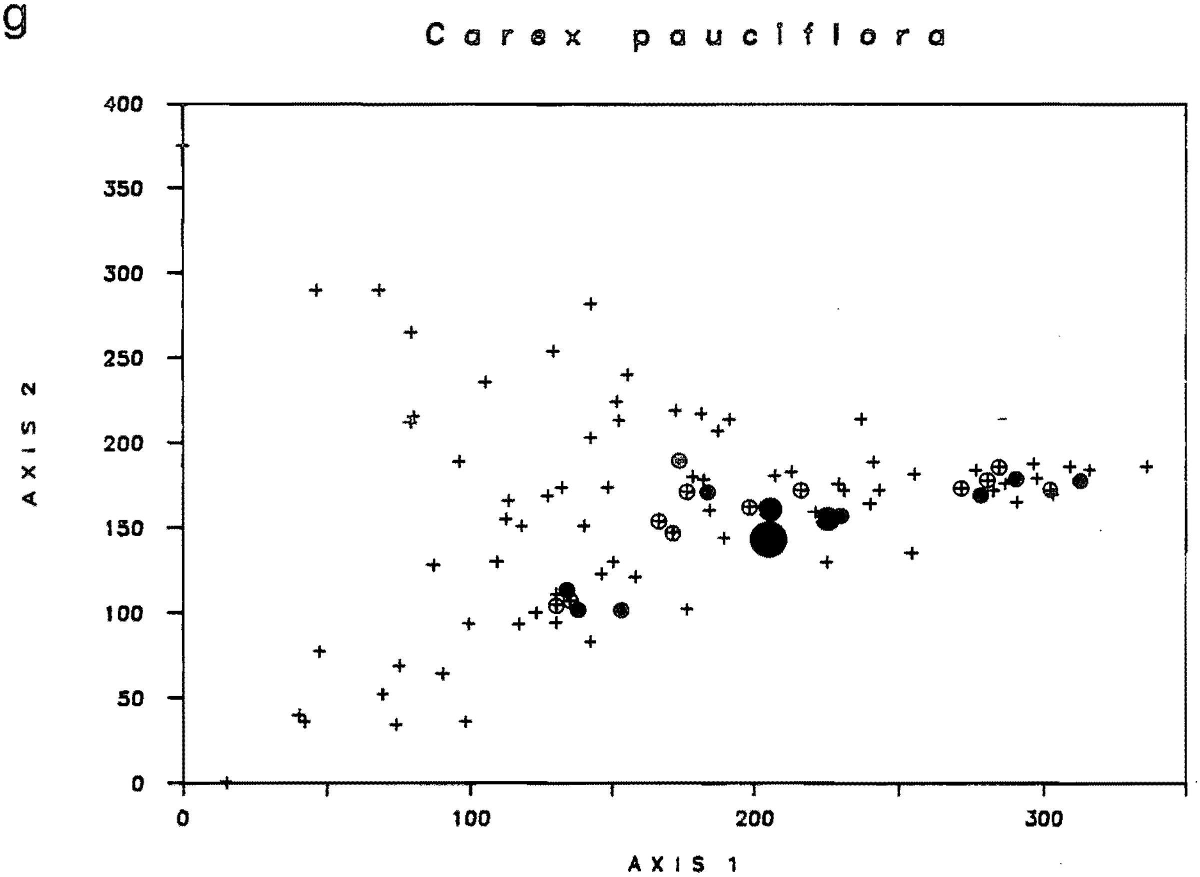
150
100
50
0
0
100
200
300

g


Carex pauciflora
AXIS 2
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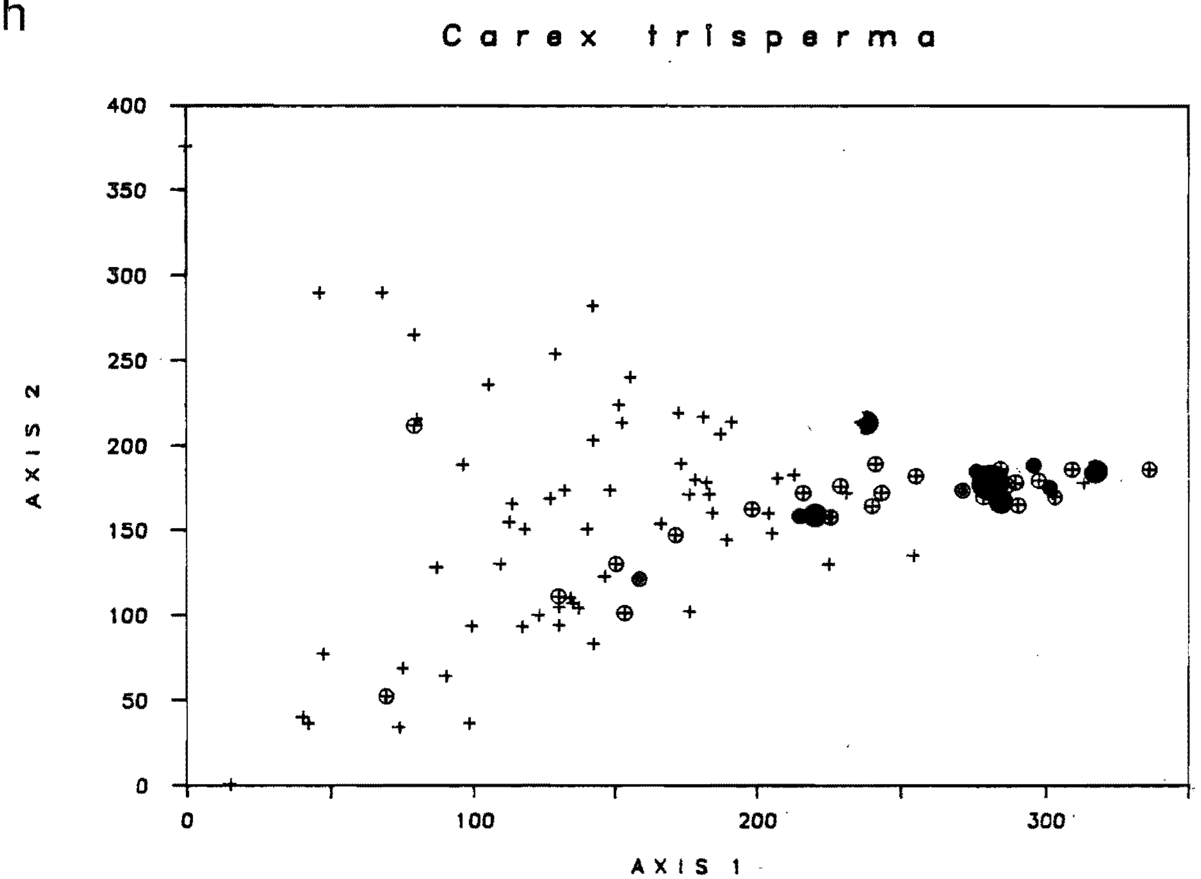
350
300
250
200
150
100
50
0
0
100
200
300
AXIS 1

h


Carex trisperma
AXIS 2
400
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0
100
200
300
AXIS 1

Table 9: Comparison of the abundance of sedges and mosses at Wanapitei and Ranger, as indicated by prominence values.

	Minerotrophic		Oligotrophic		Shrubs		Trees	
	Ran	Wan	Ran	Wan	Ran	Wan	Ran	Wan
Sedges	74.6	27.5	61.9	49.3	48.9	25.0	32.5	12.2
Mosses - <u>Sphagnum</u>	56.8	57.6	66.3	45.8	89.2	67.7	85.1	50.4
- other	0.4	5.8	3.2	9.5	0.6	14.6	3.7	15.0

At the high moisture, pool edge end of the spectrum, the degree of minerotrophy splits the vegetation into two distinct types that more or less correspond to the initial poor fen and bog classifications. Such a split was evident in a study of "kettle-hole" bog vegetation in northern Michigan (Vitt and Slack 1975). They looked at peatland vegetation surrounding central pools or lakes, as in this study, and found distinctive "acidic lake edge" and "alkaline lake edge" zones. These zones corresponded to mean pHs of 5.3 and 6.7 and calcium levels of 3.5 and 7.7 mg/l, respectively. There are marked similarities in vegetation between their zones and our groups. The sedges <u>Rhynchospora alba</u> and <u>Carex limosa</u>, yellow-eyed grasses <u>Xyris</u> spp., the cranberries, and the sundews, are abundant, if not characteristic, of both their acidic lake edge zone and our wet oligotrophic group. Their alkaline lake edge zone is not quite so similar to the wet minerotrophic group studied here, but both have <u>Carex lasiocarpa</u> as a dominant sedge and <u>Hypericum virginicum</u> as a characteristic species of the zone. These similarities are somewhat surprising given the substantially higher pH and calcium levels in the Michigan study. Acidic pool edge species such as <u>C. limosa</u> and <u>R. alba</u> remain the dominant sedges at pool pHs as low as 3.9 and calcium concentrations of 0.3 mg/l in this study, in apparent contradiction to their generally accepted status as indicators of some degree of minerotrophy (e.g. Heinselman 1970, Glaser et al. 1981, Vitt and Bayley 1984). Vitt and Bayley (1984) found that <u>C. limosa</u> occurred only in areas where pH was higher than 4.7, in a mire in northwestern Ontario. Apparently the presence of open water at the pool edge, even with chemistry typical of ombrotrophic conditions, can substitute for more minerotrophic conditions for these species.

With the exception of the low pHs tolerated by the above species, the positions of the various sedge species in the vegetational ordination (Fig. 15) are consistent with published literature for each species. C. lasiocarpa is generally acknowledged as an indicator of minerotrophic conditions, often at pool edges or fen flarks (Heinselman 1970, Vitt and Slack 1975, 1984, Glaser et al. 1981, Larsen 1982, Vitt and Bayley 1984). C. Pseudo-Cyperus is also indicative of fen-like conditions (Glaser et al. 1981), while C. oligosperma, C. pauciflora and C. trisperma are present in oligotrophic or ombrotrophic situations (Glaser et al. 1981, Gorham et al. 1985b), as seen in Figure 15. The wet to dry gradient of C. limosa through C. oligosperma to C. trisperma is also well-documented in the literature (e.g. Vitt and Slack 1975, Glaser et al. 1981).

The vegetation sampled in this study is well-represented by indicators of ombrotrophy and poor minerotrophy, but almost lacking in rich fen indicator species (see for example species listed by Heinselman 1970 and Sparling 1973). Forested fen vegetation is also not abundant at either Wanapitei or Ranger. In fact, the drier portions of both fens and bogs sampled in this study are similar vegetationally, consisting primarily of species indicative of weak minerotrophy or ombrotrophy. This similarity is not surprising given the fact that mat water chemistry in these two types of peatlands is not greatly different (see previous section of this report).

Vegetation stands from both Wanapitei and Ranger span the range of conditions present, from wet to dry, and ombrotrophic to minerotrophic. There was an almost equal division of stands from each area into the four major habitat groupings, thus indicating no major vegetational differences between the two areas. Some species differences were discernable between the two areas, e.g. the almost complete lack of Sheep Laurel (Kalmia angustifolia) and Carex aquatilis at Ranger, the lack of C. pauciflora and scarcity of Andromeda glaucophylla and Gaultheria hispidula at Wanapitei. These differences were not part of any consistent pattern, and are likely related to biogeographic differences rather than a consequence of acid precipitation. Two consistent differences between the study areas were noted. First, there was a lesser abundance of Sphagnum and greater abundance of other mosses in the oligotrophic habitats at Wanapitei. The reason for this is not clear, but would require detailed study of the species involved before being resolved. Second, there was a lower total abundance of sedges in each habitat group at Wanapitei compared to Ranger. Gorham et al. (1984) hypothesized that poor fen vegetation, including sedges, could be displaced by more acidophilic Sphagnum vegetation as a result of acid precipitation. While it is possible that this is occurring at Wanapitei, more detailed examination of Sphagnum species present would be need before reaching any conclusions, especially since Sphagnum cover was lower at Wanapitei than Ranger.

In conclusion, the peatland vegetation of Wanapitei and Ranger can be arranged by degree of minerotrophy and dryness/shade of the habitat, as in previous peatland studies. Bog and poor fen conditions are present in both study areas but rich fen vegetation is generally lacking. Bog/fen differences are predominant at the high moisture end of the spectrum, as at the pool edges. Differences related to acid precipitation could not be ascertained, though minor effects of acid rain would be difficult to observe in such a regional comparison. Habitat for wildlife appears to be very similar in the two study areas, though there is a lower abundance of sedge vegetation at Wanapitei relative to Ranger.

5. AQUATIC FAUNAL COMMUNITY OF PEATLANDS

5.1 INTRODUCTION

In this part of our study we were interested in examining the occurrence and abundance of aquatic animals of peatland pools in relation to acidity in these organic habitats. This is of particular importance since the water chemistry data presented earlier indicated an increase in mineral acidity in peatland pools at Wanapitei, which receive higher acid deposition inputs than pools at Ranger. Aquatic organisms are a very important food source for many species of aquatic and terrestrial wildlife, and therefore are a link between pool acidity and wildlife.

Effects of acid precipitation on many aquatic biota are well studied (see for example review by Haines 1981), though effects on organisms in brown-water systems are less well-known. Organic substances are thought to ameliorate the toxicity of low pH and high metals to biota (Havas et al. 1984) particularly fish (e.g. Sloan and Schofield 1983). On the other hand, amphibian breeding appears to be more sensitive to acidity in organic systems than in clear water (Dunson and Connell 1982; Freda and Dunson 1986, cited in Freda 1986).

Animal taxa studied here include aquatic invertebrates, fish, and the aquatic stages of amphibians. Since we were primarily interested in organisms available to terrestrial wildlife as food, benthic sampling included only those invertebrates present near the benthos/water interface, and therefore available to predators. The presence or absence of fish is known to have a strong influence on the composition of the invertebrate community (e.g. Henrikson and Oscarson 1978, Eriksson et al.

1980, Morin 1984a, Bendell and McNicol in prep. a). Therefore, abundances of many invertebrate taxa were analysed with respect to fish presence/absence, and with respect to chemical conditions in fishless pools.

The data presented here are preliminary in nature, primarily because detailed identification of aquatic invertebrates has not yet been completed. Thus species that respond differently to acidification may have been clumped together into higher taxonomic groups. (Note: Appendix 2 contains a more detailed listing of taxa identified to date than is presented in this section of the report). Nevertheless, major patterns of response can be seen and provide direction for future research.

5.2 METHODS

5.2.1 Fish Trapping

Fish populations were assessed using cylindrical minnow traps (1.0 m long by 0.3 m diameter) constructed of 6 mm wire mesh, with openings 40 mm in diameter at each end. Four traps were placed in the littoral zones of each peatland during July, baited with dog food biscuits, and left for approximately 24 hours (20-28) until collected. Fish were preserved in 10% formalin for later counting and species identification. Two pools were too shallow for the use of minnow traps. Both were very acid (pH < 4.0) and no fish were collected in sweep net samples.

Minnow traps were also effective for certain larger aquatic invertebrates (e.g. leeches, Hirudinea; giant water bugs, Belostomatidae; large diving beetles, Dytiscidae - genus <u>Dytiscus</u>) and for green frog (<u>Rana</u> <u>clamitans</u>) tadpoles.

5.2.2 Amphibian Egg Masses

The edges of all peatland pools were checked for amphibian egg masses during each spring visit beginning 11 May at Ranger and 16 May at Wanapitei. Most wood frogs (Rana sylvatica) had finished breeding by this time. Visits to each peatland were one to two weeks apart. Egg mass locations were noted so that hatching success could be determined on subsequent visits.

Egg masses of wood frogs and mole salamanders (Ambystoma spp.)* were easily located and counted by this technique, and it is therefore likely that most were found. American toad (Bufo americanus) egg masses were also easy to spot but the egg stage is very short (3-12 days, DeGraaf et al. 1983) so that masses laid shortly after one visit would likely have hatched before the next visit. Toad egg masses that didn't hatch remained visible for several weeks.

* Note: two species of mole salamanders, the spotted salamander Ambystoma maculatum, and the blue-spotted salamander A. laterale, were present in the study peatlands. Egg masses were assigned to the former species since an adult spotted salamander was found laying eggs in one of the three pools with egg masses. It is possible that some A. laterale egg masses were included as A. maculatum egg masses.

5.2.3 Sweep Netting

Sweep samples were taken using a long-handled aquatic dip-net with a 30 cm rim diameter and 1 mm size mesh. Samples were taken from shore in the littoral edges of pools. Each sample consisted of one sweep through the water column and one sweep along the benthic surface. Five samples (3 at 3 small pools) were taken during each of 5 visits for a total of 25 (or 15) samples per peatland. Collection visits corresponded to the following times of the year: late May, early June, late June, mid-July, and mid-August.

Invertebrates, fish and tadpoles in the samples were counted and preserved in alcohol for further identification. Sweeping was effective for limnetic invertebrates (e.g. corixids, notonectids, dytiscids) as well as those taxa associated with submerged vegetation or benthic surfaces (e.g. molluscs, odonates, tadpoles). Small dipteran larvae were frequently collected but are probably underrepresented in these samples due to their small size and the preference of some for benthic sites. Because of the difficulty in standardizing sweep-net sampling, the actual numbers of organisms counted were not used in analyses. Instead, the frequency of occurrence of each taxon in all samples from a pool was calculated as an index of abundance.

5.2.4 Odonate Emergence

Two 5-m transects were marked out along the edge of each peatland pool for the purpose of quantifying odonate emergence. Beginning in late May with the emergence of the first dragonfly (observed 21 May), each transect was inspected for exuvia back to at least 1 m from the pool edge. All exuvia were removed from the transect, sorted into six groups by appearance (damselflies (Zygoptera) plus 5 phenotypically different dragonfly (Anisoptera) taxa), and counted. Transects were visited approximately every 2 to 3 weeks until mid-August, when emergence had virtually ended for the season.

This technique appeared to work well with all sizes of dragonfly exuvia, though it probably missed many damselfly exuvia due to small size and cryptic appearance. Heavy rainstorms occasionally washed exuvia off of pool-edge vegetation onto the mat or into the water, where some would not be found. However, this problem is not likely to have biased the relative numbers of various odonates found in each peatland.

The presence and/or abundance of particular aquatic organisms is compared to pool pH. Unless otherwise noted, pH values presented are means from three sampling periods: November 1984, May 1985, August 1985. Other chemical measures are from single lab measurements as noted in the text.

Ordination of the aquatic community was obtained using detrended correspondence analysis (DECORANA, Hill 1979), which compares the relative abundance of the aquatic taxa in the peatland pools. All correlation coefficients presented are from non-parametric Spearman rank correlations.

5.3 RESULTS

5.3.1 Fish Populations

Twelve of the thirty-one peatland pools had fish populations, including all eight fen pools at Ranger and four of eight fen pools at Wanapitei. A total of eight fish species were trapped, including five Cyprinid species (pearl dace, Semotilus margarita; redbelly dace, Chrosomus eos; finescale dace, C. neogaeus; fathead minnow, Pimephales promelas; common shiner, Notropis cornutus), the brook stickleback (Culaea inconstans), the Iowa darter (Etheostoma exile), and the white sucker (Catostomus commersoni) (Table 10). The latter was represented by only two individuals in one peatland. This pool is connected by a small stream to a nearby lake. All other fish are small non-game fish.

The five fish species most often occupying peatlands (Table 10) inhabited a large pool at Wanapitei with a mean pH of 4.83. This pool had pH values ranging from 4.53 in fall 1984 to 5.10 in summer 1985, and DOC levels averaging 15.4 mg/l. Fathead minnows were present at pH 5.58, Iowa darters and suckers at pH 5.93.

Four Wanapitei pools with outflows had no fish in them. Mean pHs in these pools were 4.31, 4.94, 5.33, and 5.48. The latter two pools had only temporary outflows that probably restricted colonization by fish, but this was not true of the former two. Bog pools were all isolated hydrologically, had low pHs (3.99-4.94), and were fishless.

5.3.2 Amphibian Eggs and Larvae

Several species of amphibians bred in peatland pools, as evidenced by egg masses and larvae. Spotted salamanders were represented by egg masses only, spring peepers (Hyla crucifer) and green frogs by tadpoles only, and toads and wood frogs by both egg masses and tadpoles. Several other species of amphibians were present at peatland pools as adults (see next section on terrestrial wildlife), but no evidence of breeding was found. Adult red-spotted newts (Notopthalmus viridescens) were present in at least three pools. Data presented here are preliminary since tadpoles of wood frogs and spring peepers will require species verification, and some tadpoles classed as green frogs could have been mink frog tadpoles (Rana septentrionalis). See also the earlier note regarding salamander egg mass identification.

Table 10: Fish species caught in minnow traps in 31 peatland pools (both study areas combined), listed in order of abundance, with range of mean pHs where each species was trapped.

Fish Species	Peatlands occupied	Total Abundance	Fish per Peatland	pH Range
Chrosomus eos	9	3,525	392	4.83-6.99
Chrosomus neogaeus	11	2,969	270	4.83-6.99
Culaea inconstans	10	348	35	4.83-6.99
Semotilus margarita	6	171	29	4.83-6.99
Pimephales promelas	2	72	36	5.58-6.99
Notropis cornutus	3	16	5	4.83-6.99
Etheostoma exile	2	8	4	5.93-6.99
Catostomus commersoni	1	2	2	5.93
Without fish	19	0	0	3.99-5.48

Table 11: pH distribution of breeding by amphibians, both study areas combined. (a) all eggs in at least 1 egg mass didn't hatch. (b) eggs in at least 1 egg mass developed. (c) presence of larvae. The number of peatlands in each category is given in parentheses, and total number of pools with breeding evidence (eggs and/or larvae) is listed in (d).

Amphibian Species	(a) Eggs Didn't Hatch	(b) Eggs Developed	(c) Larvae Present	(d) All Breeding
Ambystoma maculatum	4.46 (1)	4.46-6.18 (3)		3
Bufo americanus	4.10-4.46 (6)		5.52-6.18 (3)	9
Hyla crucifer			4.46-5.97 (10)	10
Rana sylvatica	4.10-4.40 (2)	4.30-6.18 (11)	4.45-6.18 (11)	18
Rana clamitans			4.46-6.18 (14)	14

A total of 58 salamander egg masses, 10 toad egg masses, and 325 wood frog egg masses were censused in peatland pools. The majority of these, including all salamander egg masses, 7 toad egg masses and 310 frog egg masses were found at Ranger. The low number of wood frog egg masses found at Wanapitei (15) may be biased since the masses found were near hatch when pools were first visited in mid-May.

The pH distribution of egg masses and larvae for the five species of breeding amphibians is presented in Table 11. It appears that a pH level of between 4.3 and 4.5 is critical for some, if not all, of these species. Of 15 salamander egg masses found at pH 4.46, at least 3 failed to hatch any larvae, and several others developed fungal growths before hatching. The fate of larvae in this pool is unknown since we were unable to find salamander larvae in any of the three pools where eggs developed. Toads also appeared to have trouble with pHs of 4.46 and below. Six pools with pHs ranging from 4.10 to 4.46 had toad egg masses that did not develop. Toad tadpoles were not found in any of these pools, and in fact were not found until pH reached 5.52. Wood frogs appeared to be only slightly more tolerant to low pH than the previous two species. Approximately 75% of eggs appeared to develop normally in two pools of pH 4.30 and 4.31, though subsequently tadpoles were not seen in either pool. Egg masses failed to hatch at pHs of 4.10 and 4.40, and tadpoles were not observed at pHs below 4.45. Tadpoles were able to develop to adult stage at pH 4.45.

It is not possible to establish a critical pH for spring peepers or green frogs without knowing where these species laid eggs. However it is significant that tadpoles of both species were present only at pH 4.46 and above, as in the previous species.

The fact that these amphibians have difficulty breeding when bog pH falls below 4.3-4.5 is important in the context of the present study. This pH range is higher than all bog pools sampled at Wanapitei, yet allows for breeding in most bog pools at Ranger. The drop of about 0.3 pH units from Ranger bog pools to Wanapitei bog pools corresponds to a doubling of hydrogen ion concentration, and appears to be detrimental to amphibians.

5.3.3 Aquatic Invertebrates

The seasonal pattern of odonate emergence was similar in peatlands at Wanapitei and Ranger. Emergence began on approximately 21 May in both areas, quickly peaked at the end of May and the first week of June, and then gradually declined until the end of sampling in August. Approximately half of the total emergence of odonates occurred before 5 June in both study areas. The six taxa noted among the exuvia had distinct seasonal peaks, so that the date of 50% emergence for each taxa varied from late May for the first to emerge, to mid-July for the last (Table 12). Emergence dates were similar for all but one group, referred to here as dragonfly "D", which appeared to emerge three weeks earlier at Wanapitei than at Ranger. This possibly indicates that different species comprised dragonfly D in the two areas.

The proportion of total exuvia comprised by each odonate group was similar in the two study areas, though the abundance of some odonates, particularly damselflies, appeared to be lower at Wanapitei than at Ranger.

Table 12: Odonate emergence as quantified by exuvia counts at Ranger and Wanapitei pool edges.

	Total Exuvia		Date of 50% Emergence	
	Ranger	Wanapitei	Ranger	Wanapitei
Number of Transects	30	32		
Dragonflies (Anisoptera)				
"A" (Corduliidae)	434	539	May 30	May 27
"B" (Leucorrhinia)	1,497	1,371	June 4	June 6
"C" (Libellulidae)	80	35	June 27	June 21
"D" (Leucorrhinia)	105	50	July 7	June 15
"E" (Aeshnidae)	67	51	July 11	July 16
Damselflies (Zygoptera)	192	44	June 12	June 10

The replication of transects for counting exuvia at each pool allowed us to check the amount of variation attributable to within-pool and among-pool differences in emergence. At Ranger, there was a highly significant difference in total odonate emergence among pools ($F = 18.7$, $df = 14,15$, $P < 0.001$), with 54.1% of the variation explained by differences between pools. Results were similar at Wanapitei ($F = 24.9$, $df = 15,16$, $P < 0.001$; 59.9% of variation explained by difference among pools). Therefore further analyses of odonate emergence use data summed from the two transects.

An ordination of the aquatic animal community, as described from frequencies in sweep net samples, separates the peatland pools into three distinct groups (Fig. 16). The first axis separates pools with fish (high on axis 1) from pools without fish. The second axis splits the fishless pools into two groups which differ in pH and in the relative abundance of various taxa (Table 13). Both axes were correlated with pH more strongly than any other chemical variable ($r_s = 0.69$, $df = 29$, $P < 0.001$ for axis 1; $r_s = 0.55$, $df = 29$, $P < 0.01$ for axis 2; spring 1985 data).

The pools with fish have a relatively high calcium content (median of 3.26 mg/l) and pH (median of 5.93). Invertebrates which were only found in these pools include amphipods, snails (Gastropoda) and crayfish (Decapoda, only 2 found). Leeches, pill clams (Sphaeriidae), and green frog tadpoles (from minnow traps) were also most abundant in these minerotrophic pools. Fishless pools contained a higher abundance of many insect groups, particularly nektonic taxa such as the hemipterans Notonectidae (backswimmers), Corixidae (waterboatmen), and Nepidae

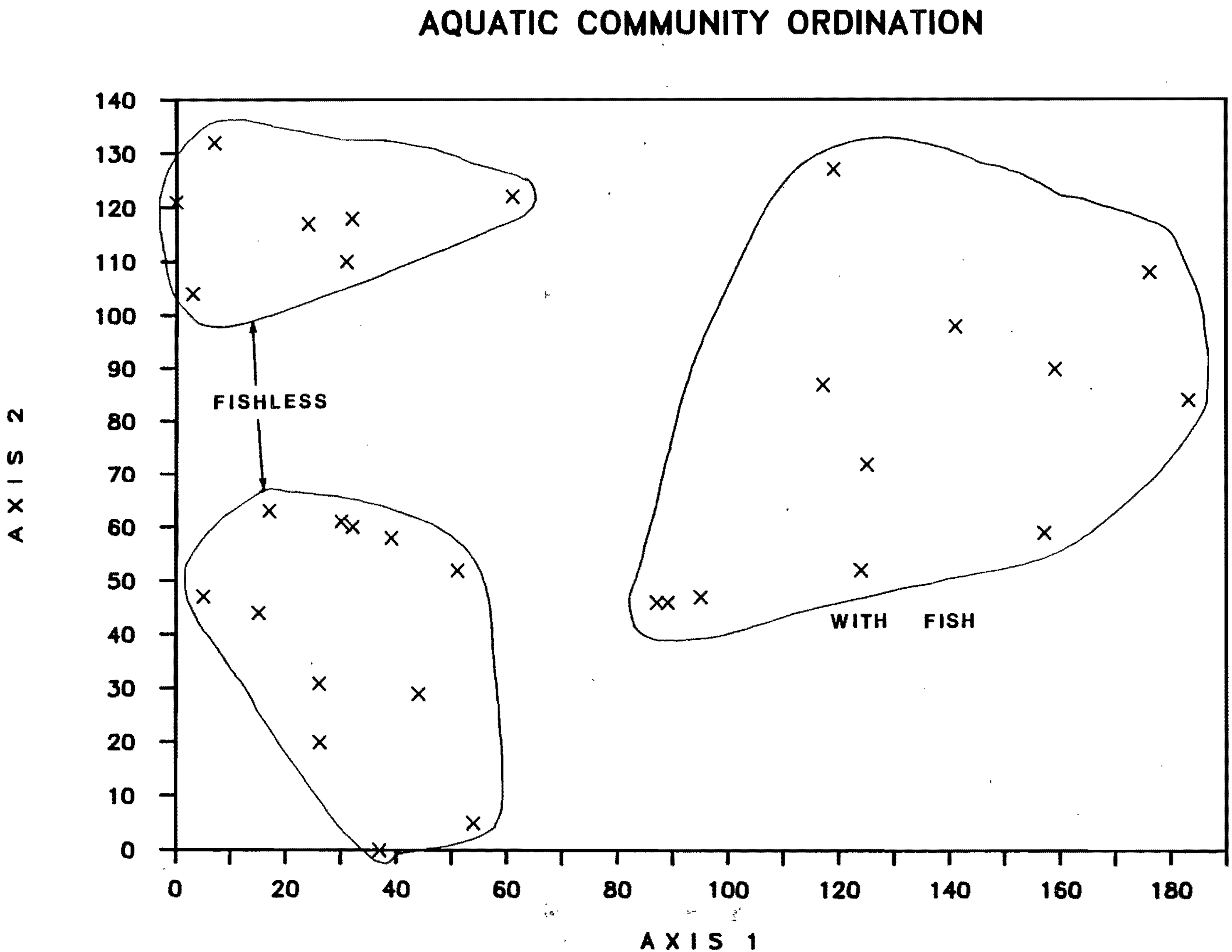


Figure 16: Ordination of the aquatic animal community from frequencies of taxa in sweep net samples. Each point represents one pool (15-25 samples). Three groups of pools are delineated for further analyses.

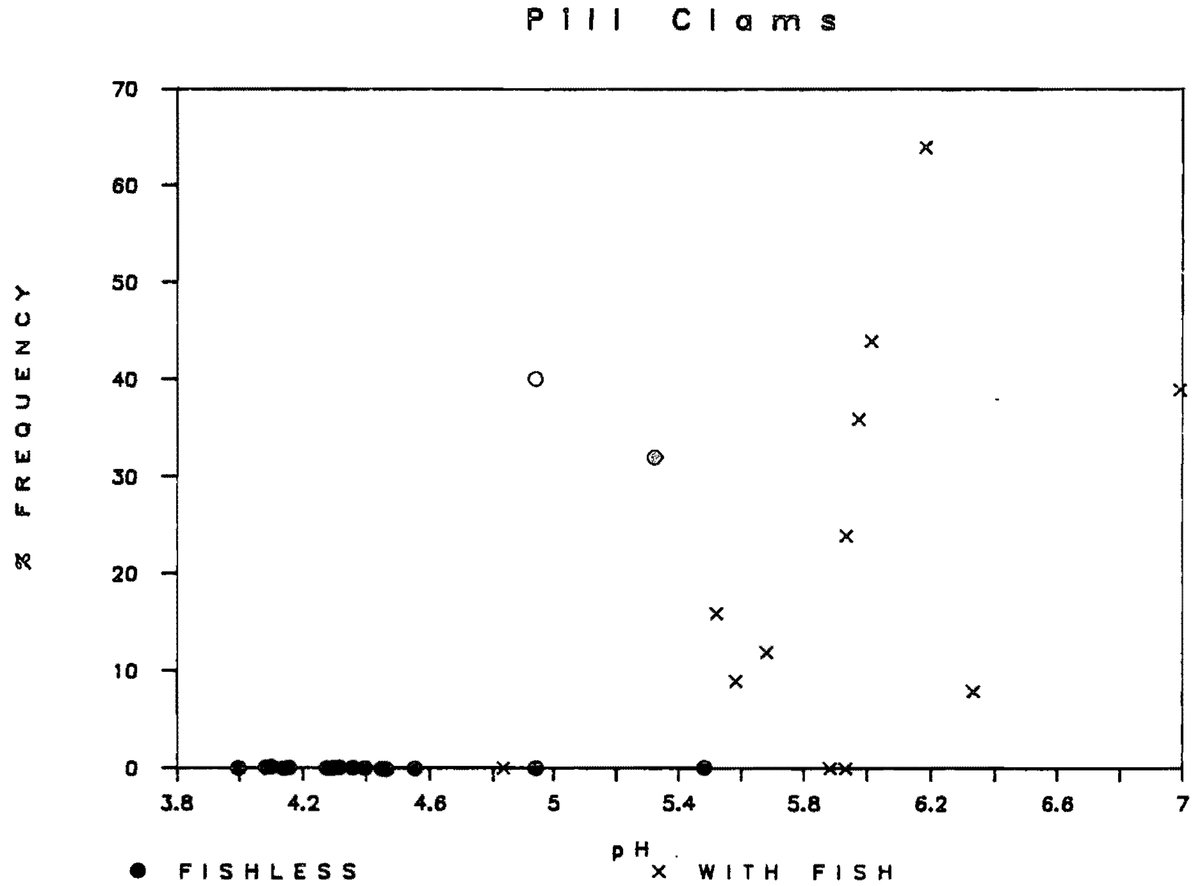
(waterscorpions), and the coleopterans Dytiscidae (diving beetles) and Gyrinidae (whirligig beetles). Benthic groups such as Anisoptera, Trichoptera (caddisfly), and Diptera larvae, as well as the neustonic Gerridae (waterstriders) were also most abundant in fishless pools. Odonate emergence was generally greater from fishless pools, though one taxon, dragonfly "C", was most abundant around pools with fish.

Within fishless pools most organisms were more abundant in the pools with relatively high pH (4.94 vs. 4.15). A comparison of bog pools at Ranger with bog pools at Wanapitei also indicated that most taxa were more abundant at Ranger. The only exceptions were the waterstriders, giant water bugs, and dragonfly larvae. The latter exception was probably due to larvae of dragonfly "B", which emerged in slightly greater numbers in the more acid fishless pools.

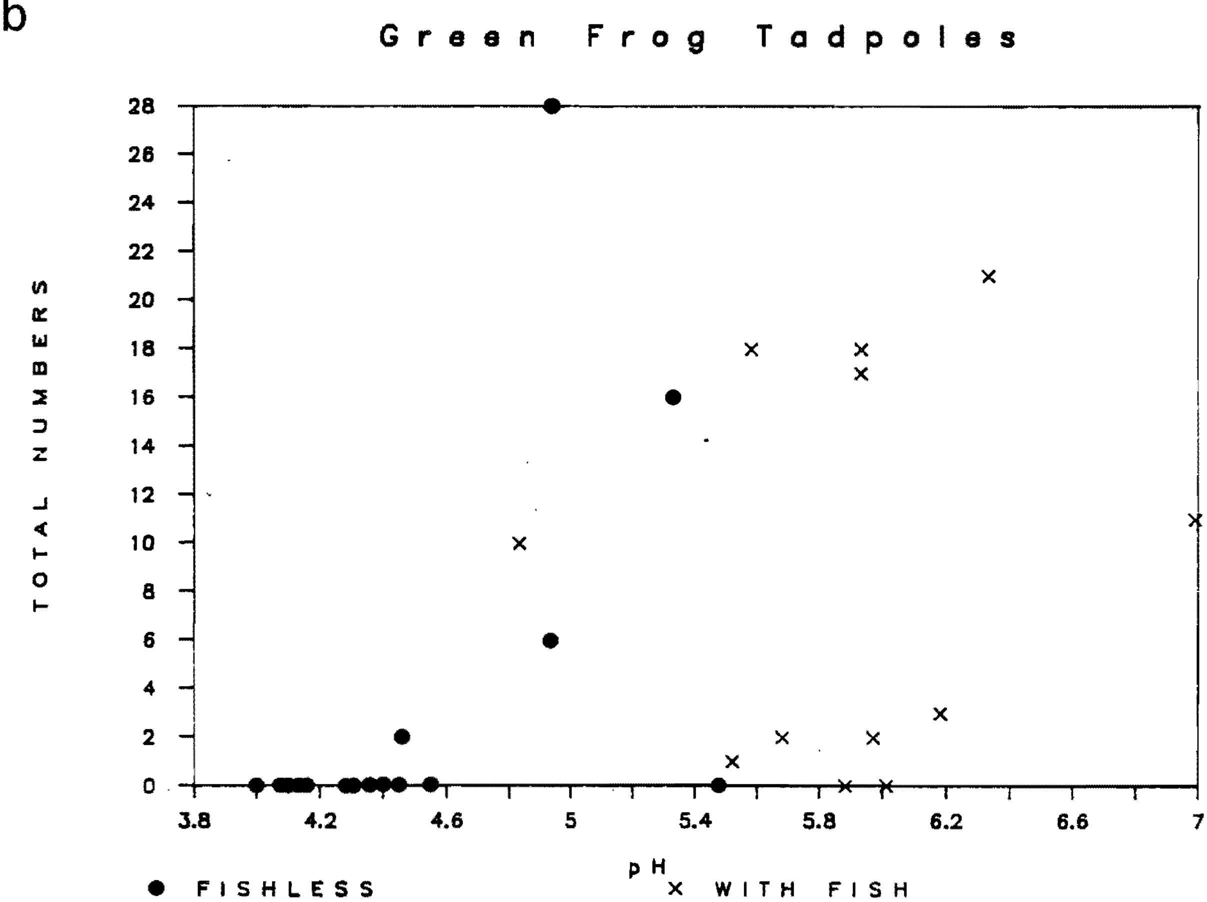
These relationships with pH were further examined by correlation analysis (abundance vs. pH). Several taxa showed a positive correlation with pH (and calcium concentration) over the entire range of pools sampled. This included fish ($r_s = 0.78$ for pH vs. abundance), clams (0.72, Fig. 17a), dragonfly "C" (0.69), green frog tadpoles (0.68, Fig. 17b), leeches (0.66), amphipods (0.58), and snails (0.51, all correlations significant at $P < 0.05$). A second group of taxa showed positive correlations with pH in the fishless pools. This group includes small tadpoles ($r_s = 0.82$), emergence of dragonfly "E" (0.79), corixids (0.77, Fig. 17c), whirligig beetles (0.69), waterscorpions (0.69), damselfly larvae (0.66), emergence of damselflies (0.55), small dytiscid beetles (0.54, Fig. 17d), trichopteran larvae (0.49), and notonectids (0.48). All of these taxa were more abundant in the moderate pH fishless

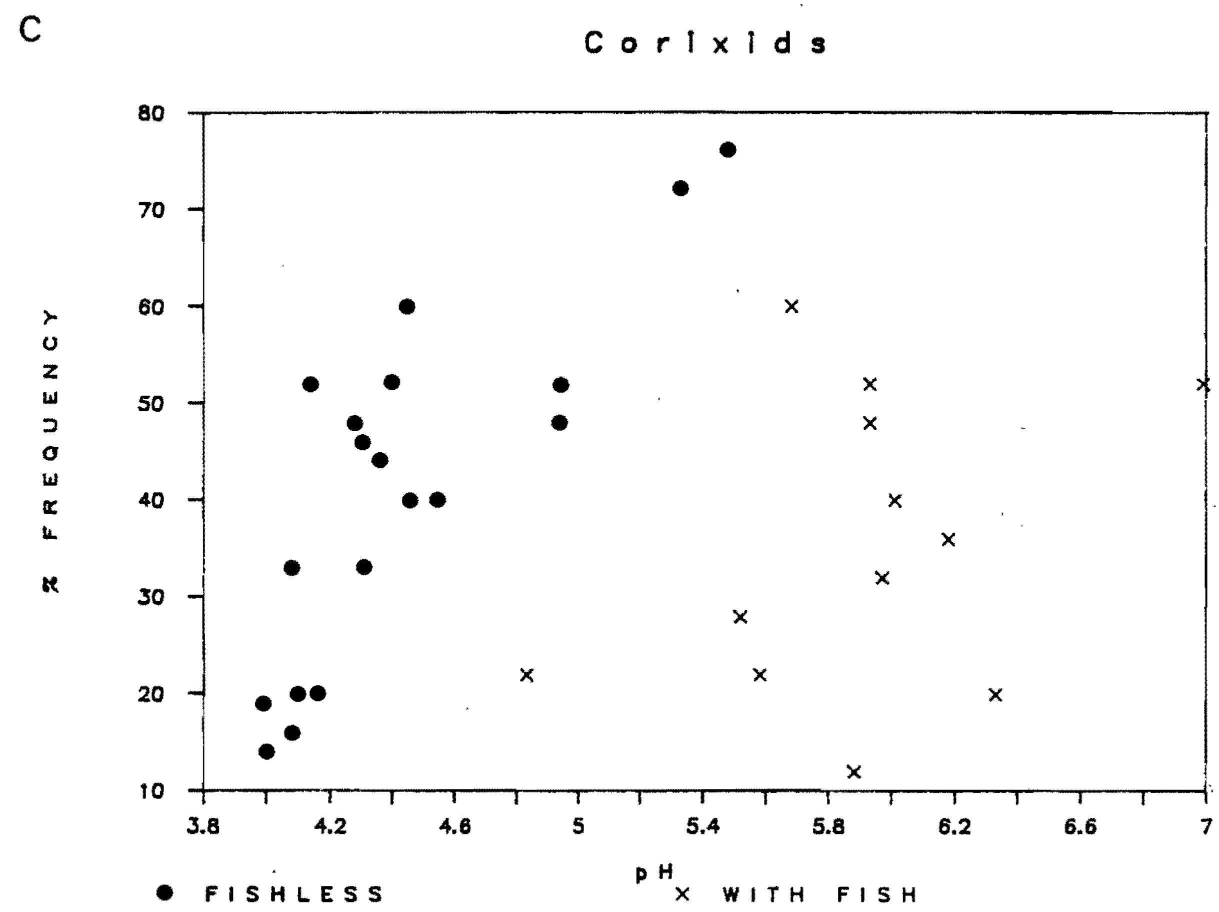
Figure 17 (a-g): Relationships of aquatic biota with pH of peatland pools. Abundances are given as percent frequencies from sweep net samples, with the exception of (b) where abundance is the number of tadpoles caught in minnow traps, and (g) where the number of exuvia counted in transects is plotted.

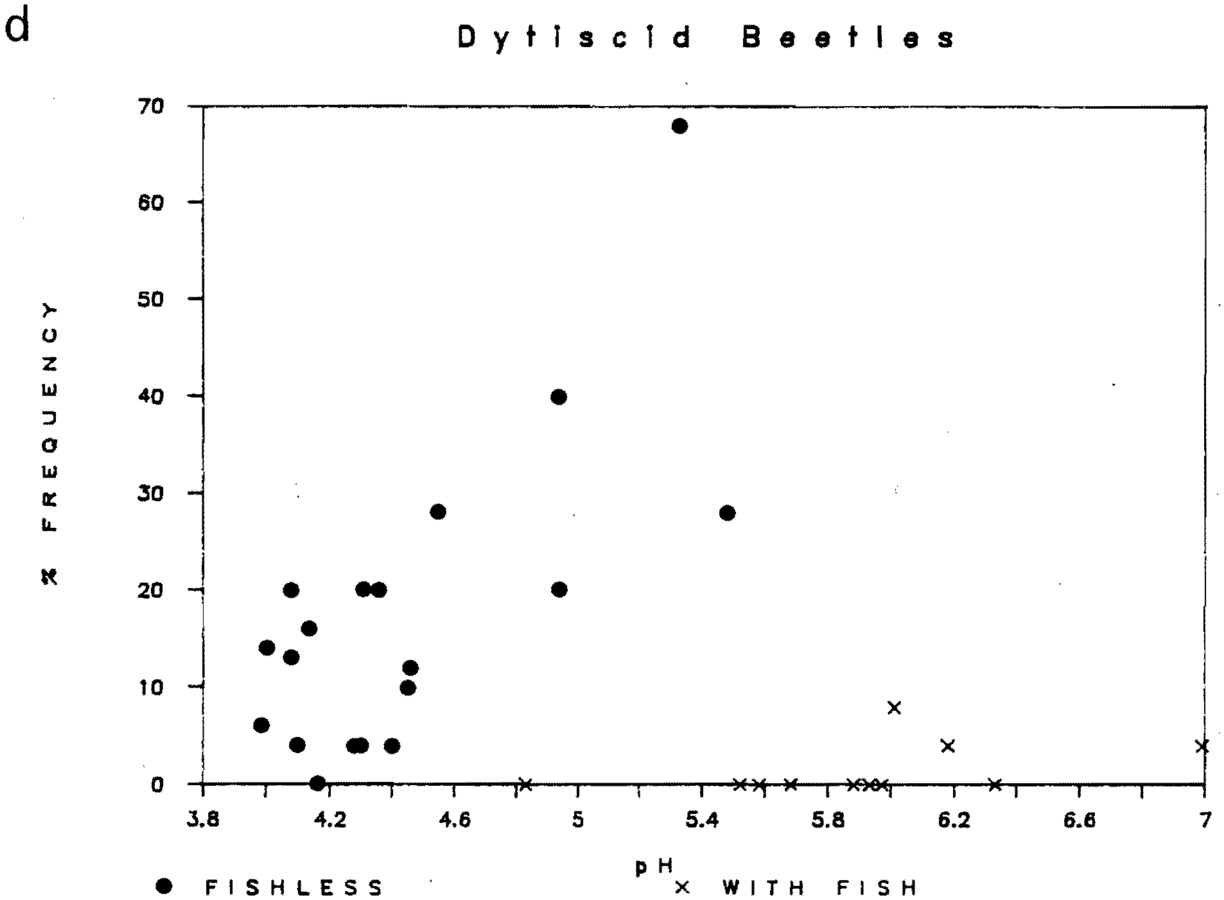
a


Pill Clams
% FREQUENCY
70
60
50
40
30
20
10
0
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
● FISHLESS
× WITH FISH

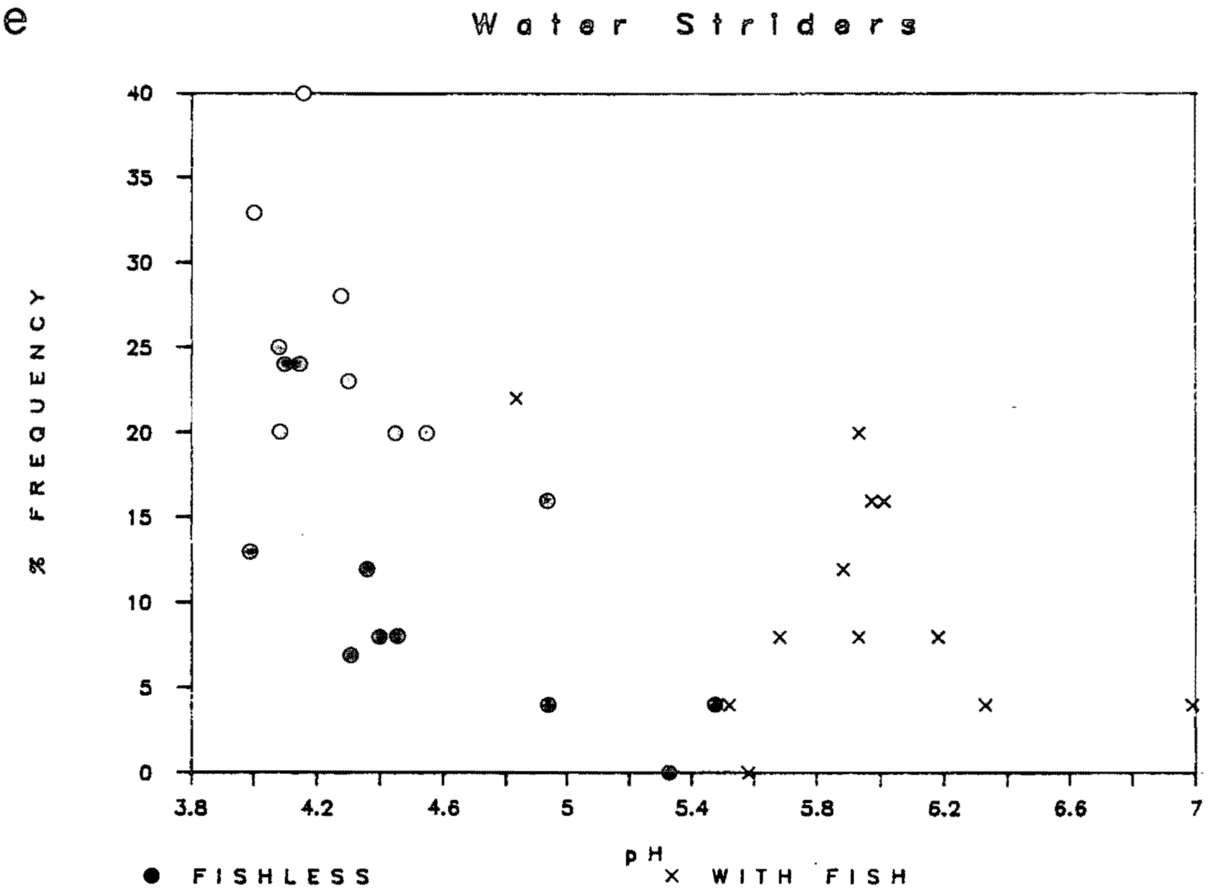
b


Green Frog Tadpoles
TOTAL NUMBERS
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
● FISHLESS
× WITH FISH

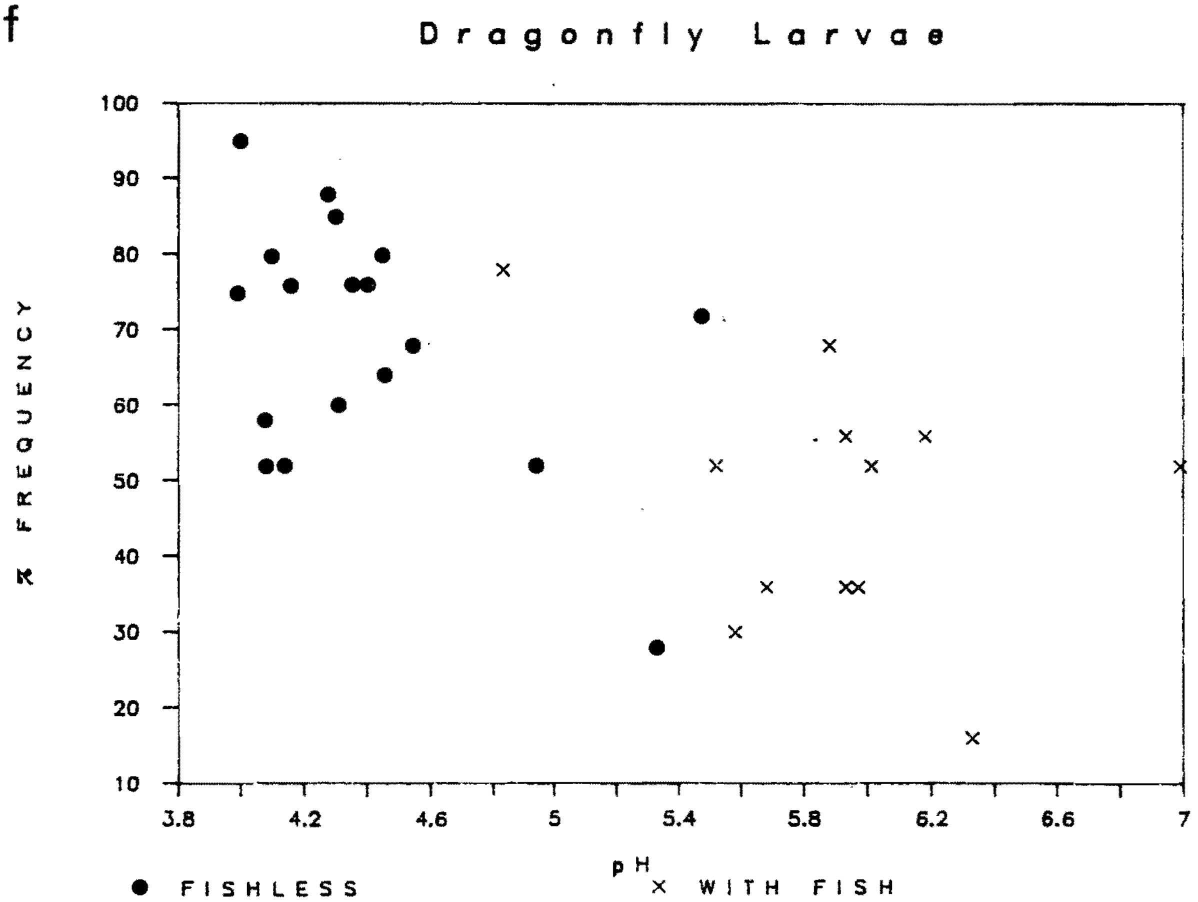

c
Corixids
% FREQUENCY
80
70
60
50
40
30
20
10
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
● FISHLESS
× WITH FISH


d
Dytiscid Beetles
% FREQUENCY
70
60
50
40
30
20
10
0
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
● FISHLESS
× WITH FISH

e


Water Striders
% FREQUENCY
40
35
30
25
20
15
10
5
0
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
FISHLESS
WITH FISH

f


Dragonfly Larvae
% FREQUENCY
100
90
80
70
60
50
40
30
20
10
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
FISHLESS
WITH FISH

g

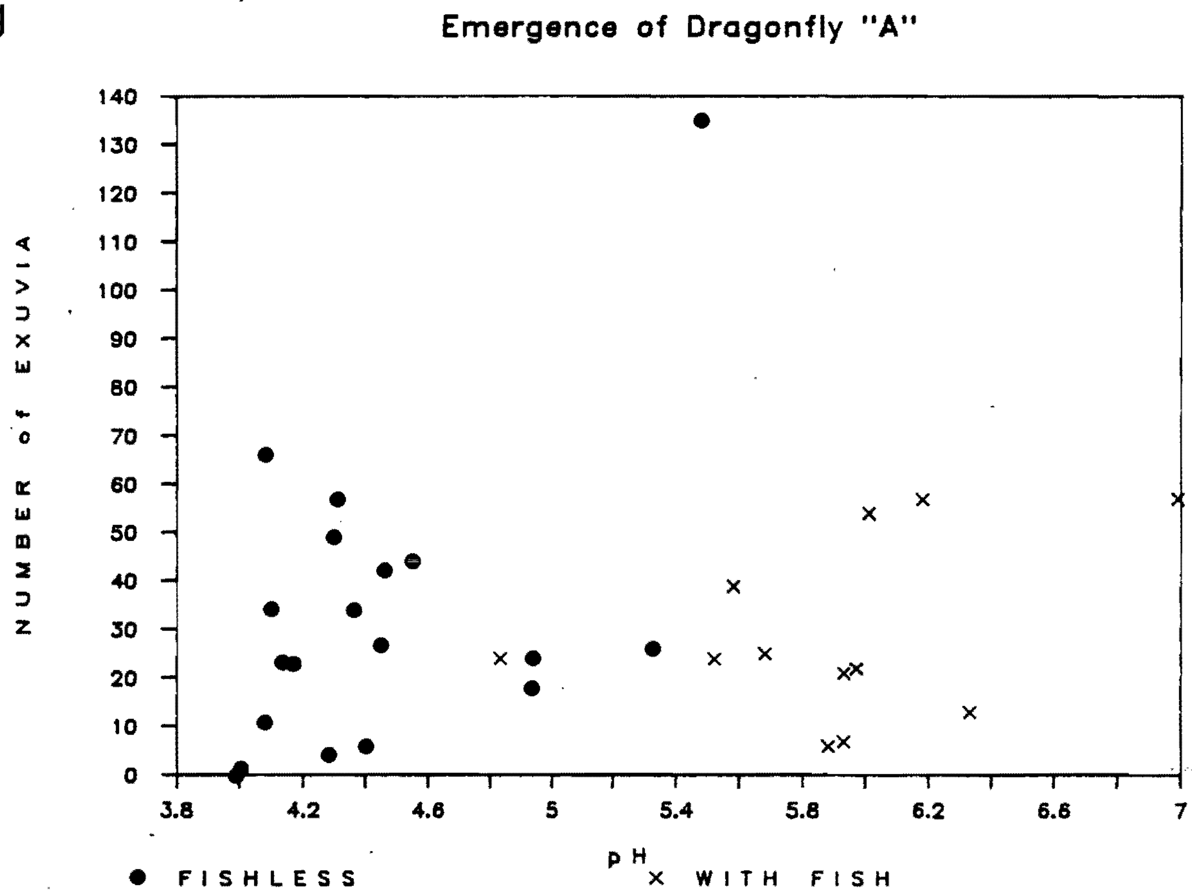

Emergence of Dragonfly "A"
NUMBER of EXUVIA
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
3.8
4.2
4.6
5
5.4
5.8
6.2
6.6
7
pH
FISHLESS
WITH FISH

Table 13: Average abundance of aquatic organisms in three groups of pools (groups from ordination shown in Figure 16). Animals from sweep nets, fish traps, and exuvia counts are included. Median pH and calcium concentrations for the three groups are also given (both study areas combined).

	FISHLESS POOLS		POOLS WITH FISH
	Low pH	Higher pH	
Number of Peatlands	12	7	12
<u>Sweep Net Samples (percent occurrence)</u>			
Gerridae	22.5	8.4	10.2
Anisoptera Larvae	74.4	56.6	47.3
Diptera Larvae	26.5	37.6	9.6
Notonectidae	32.9	45.7	8.3
Dytiscidae - Adults	9.6	30.9	1.3
- Larvae	3.1	21.1	0.7
Gyrinidae	5.1	26.1	3.7
Corixidae	35.3	51.6	35.3
Trichoptera Larvae	15.1	24.6	15.2
Nepidae	1.1	5.7	1.3
Zygoptera Larvae	3.1	38.4	7.8
Tadpoles (small)	1.3	17.7	9.8
Oligochaeta	0.7	1.7	3.2
Sphaeriidae		10.3	21.0
Gastropoda			9.5
Amphipoda			7.6
Ephemeroptera Larvae			2.1

Table 13 (cont.)

	FISHLESS POOLS		POOLS WITH FISH
	Low pH	Higher pH	
Fish Traps (mean number trapped per peatland)			
Belostomidae	7.1	3.4	3.3
Dytiscidae (Dytiscus)	0.8	0.9	1.0
Tadpoles (large)		7.4	8.6
Hirudinea		0.1	3.8
Decapoda			0.2
Odonate Emergence (mean number of exuvia per peatland)			
Dragonfly "B"	148.3	126.6	16.0
Dragonfly "D"	4.9	9.9	2.1
Damselflies	5.8	19.4	2.1
Dragonfly "E"	0.9	12.3	1.8
Dragonfly "A"	23.2	49.4	29.1
Dragonfly "C"	0.3	1.0	8.1
Chemistry			
pH - Median	4.15	4.94	5.93
- Range	3.99-4.45	4.31-5.48	4.83-6.99
Ca - Median	0.83	1.58	3.26
- Range	0.29-1.77	0.42-2.28	2.08-8.92

pools than in either pools with fish, or the more acidic fishless pools (Table 13).

Only waterstriders showed a negative correlation with pH in fishless pools (-0.69, Fig. 17e), though dragonfly larvae also tended to be most abundant in the low pH fishless pools (Fig. 17f). A few taxa showed little response to the presence of fish or to changes in pH. Large dytiscid beetles (genus Dytiscus), giant water bugs, and emergence of dragonfly "A" (Fig. 17g), belonged to this group.

The net effect of these relationships for wildlife which prey on aquatic organisms is that the highest pH pools have prey for piscivores and for those animals that require high calcium content in their food (prey such as gastropods). With the exception of a few insect taxa, prey for insectivorous species of wildlife is most abundant in the fishless pools with highest pH.

5.4 DISCUSSION

The predominance of cyprinids and brook sticklebacks in our fish assemblages is typical of bog lakes with low winter oxygen levels but relatively high pH (above 5.2, Rahel 1984). This cyprinid assemblage is a subset of the fish present in headwater lakes of the Wanapitei and Ranger study areas (McNicol et al. 1986b). Missing are the acid tolerant yellow perch (Perca flavescens), several centrarchid species, and fish more typical of stream situations. The centrarchids are sensitive to the low levels of winter oxygen that would be found in shallow peatland pools (Rahel 1984). The absence of several fish species may be due to the small size of inlets and outlets to the pools. Bendell and McNicol (in prep. b) found that fish typical of stream situations were absent from headwater lakes with small drainage basins, as is the case with the peatlands studied. The Ranger study area is not within the range of the Central Mudminnow (Umbra limi), a species typical of acid bog water in eastern Ontario (Lyons and Smith 1974) and in Wisconsin (Rahel 1984). Mudminnows have been found in one watershed at Wanapitei, but apparently have not yet spread to peatland waters there.

Our minimum pH values for all of the cyprinids and the brook stickleback are low compared to values obtained in naturally acid bog lakes in Wisconsin (Rahel and Magnuson 1983, Rahel 1984). Values obtained were similar, however, to the lowest pH's measured for these species in headwater lakes of the Wanapitei and Ranger study areas (D. McNicol, unpublished data). Generally, even in the headwater lakes, cyprinids and sticklebacks are absent from most lakes below pH 5.3, as in Wisconsin bog lakes. Thus the one fen pool with pH 4.83 and five fish species is an outlier. This is particularly true for the common shiner which is not normally found below pH 6 (Rahel 1984, McNicol et al. 1986b). The presence of fathead minnows at pH 5.58 is also unusual, since this species is known to be particularly sensitive to acidity (Schindler and Turner 1982, Rahel and Magnuson 1983). The reason for the presence of these fish at low pH is not known but could be related to the high levels of organic carbon found in bog pools, which is thought to ameliorate metal toxicity at low pH (Sloan and Schofield 1983, Havas et al. 1984). Kerekes (1982, cited in Jones et al. 1986) found that the relationship between fish presence/absence and pH in Kejimkujik National Park, an area where most river systems are highly coloured, was at approximately 0.1-0.4 pH units lower than similar relationships developed elsewhere for clearwater lakes. Alternatively, fish populations in low pH pools may be replenished periodically by immigration from less acidic refugia.

The lethal pH for amphibian breeding in our peatland pools appears to occur at about 4.2 to 4.5, at least for the wood frog, American toad and spotted salamander, and possibly for the green frog and spring peeper. For all but the salamander, this pH range is higher than reported in the literature (Pierce 1985, Freda 1986). For the wood frog, lethal pH (100% mortality of embryos) is listed in the above reviews as 3.5 to 4.0, while a decrease in hatching success (sometimes referred to as critical pH) occurs at pH's 3.5-4.25. In the present study, wood frog embryos did not hatch in pools with pH 4.1 and 4.4. While most eggs hatched in masses at pH 4.3, no tadpoles were subsequently discovered, and tadpoles were known to metamorphose only at pH 4.45 and above. It is possible that this relatively high pH range could be a result of the organic nature of the water. Dunson and Connell (1982) and Freda and Dunson (1986, cited in Freda 1986) found that organic bog water is more toxic to amphibians than non-bog water of similar pH. Nevertheless, wood frogs and spotted salamanders are known to breed successfully in bog water of pH 4.1 in Nova Scotia (Dale et al. 1985). Geographic variation in acid tolerance is well-known in amphibians (e.g. Pierce 1985) and could explain this difference.

The lower pH of bog pools at Wanapitei compared to Ranger is critical to amphibians, since natural bog waters pH's are marginal for their breeding success. Even small decreases in pH due to mineral acid inputs are therefore detrimental to amphibian populations in peatland systems such as those studied.

Invertebrate taxa that were absent at low pH in this study are those groups known to be sensitive to mineral acidity in clearer waters (e.g. molluscs, particularly gastropods, large crustaceans, leeches, mayflies; Bell 1971, Wiederholm and Eriksson 1977, Malley 1980, Raddum 1980, Okland and Okland 1980, Berrill et al. 1985). These are the groups that would be most sensitive to changes in the chemical composition of fen waters.

Many of the remaining taxa show an increase in abundance in fishless pools, relative to pools with fish, which suggests a strong influence of fish predation on the invertebrate community. This result is a frequently observed phenomenon in anthropogenically acidified waters. Moderate to large invertebrate taxa, especially those that are active in the water column, increase in abundance in the absence of fish. These taxa include odonates, corixids, notonectids, dytiscid beetles, and some dipteran larvae (Henrikson and Oscarson 1978, Eriksson et al. 1980, Henrikson et al. 1980, Morin 1984a,b, Bendell and McNicol in prep. a). Such an increase has a beneficial effect for insectivorous predators such as certain waterfowl species (e.g. Bendell et al. 1983, Eriksson 1984, McNicol et al. 1986a).

It has been hypothesized that food for these insectivorous predators would ultimately decline as pH in fishless lakes decreased still farther (DesGranges 1982, McNicol et al. 1986a). Such a phenomenon appears to be occurring in the fishless peatland pools of Wanapitei and Ranger - the pools with lowest pH have lower abundances of most invertebrate taxa. The lower pH of bog pools at Wanapitei relative to Ranger is therefore reflected in lower abundance of most invertebrate taxa, in addition to the lack of amphibian breeding success mentioned previously.

In conclusion, the pH of peatland pools is of great importance to the makeup of the aquatic animal community, regardless of whether acidity is organic or mineral in nature. Fish and several non-insect invertebrates disappear from fen pools when pH drops below about 4.5–5.5, amphibian breeding success drops to zero at about pH 4.3 in bog pools, and further declines in pH result in lower abundances of most of the insect taxa characteristic of fishless pools. The result is that fewer fen pools have fish at Wanapitei than at Ranger, and bog pools at Wanapitei have a lower abundance of most aquatic organisms compared to bog pools at Ranger.

6. TERRESTRIAL WILDLIFE

6.1 INTRODUCTION

Changes in peatland vegetation or aquatic animal populations due to anthropogenic acidification will eventually affect terrestrial wildlife, through changes in either habitat characteristics or food resources. In the present study there is evidence for a depression in pH related to the higher mineral acid input at Wanapitei. This has consequences for the aquatic animal community, which is sensitive to differences in acidity. As a result, we would expect wildlife which rely on aquatic food sources in peatlands to be at risk. Our purpose in this portion of the study was to identify those wildlife species which could be affected by acid precipitation induced changes in peatlands. Specific objectives were (1) to quantify the use of peatlands by breeding birds and small mammals, particularly those species which might be using food from the aquatic environment, and (2) to look for preliminary evidence of acidification effects on a breeding insectivorous bird, the Tree Swallow (*Tachycineta bicolor*). Additional information is presented on the occurrence of adult amphibians at peatland pools.

6.2 METHODS

6.2.1 Amphibians

The presence and/or calling of adult amphibians at peatland pools was noted during regular visits to each pool. No attempt was made to obtain a quantitative estimate of the number of amphibians present. Pitfall traps placed around the pool to catch small mammals (see below) also captured many amphibians.

6.2.2 Mammals

Three 3.5-l plastic pails were sunk into open sphagnum mat or sedge mat communities at a distance of 2-10 m from each pool. These pitfall traps were filled 1/3 to 1/2 with water, and checked during each peatland visit for small mammals and amphibians. Mammals were weighed and measured (body length, tail length, hind foot length) for identification purposes. Skulls of the smaller shrews were kept to aid with identification.

Relative rates of capture for each species were compared on the basis of captures per 1000 trap-nights. Traps which had been rendered inactive (i.e. removed from the mat) by large mammals were not included in these calculations. Ravens (Corvus corax) were observed to rob pitfall traps, and mammal droppings by a few traps indicated that some captured animals were lost to predators. Since these traps still produced captures, they have been included in the results as if there was no disturbance. Capture rates presented are therefore lower than actual rates.

Use of peatlands by other large mammals was noted, from actual sightings, fresh tracks, feces or lodges.

6.2.3 Birds

6.2.3.1 Breeding Bird Surveys

As part of an aerial survey of waterfowl pairs in headwater lakes (see Ross 1985), peatland pools were surveyed for waterfowl on 12 May 1985 at Wanapitei, and 15-16 May at Ranger. Each peatland was checked once. Further notes on the use of peatland pools by waterfowl were made during routine ground visits to peatlands in May to August.

Ground surveys of calling birds were made twice during June in all peatlands - once during the first half of June, and again in the latter half of June. This involved a modification of the mapping technique used to estimate densities of breeding birds (i.e. Anonymous 1970). A grid of calling stations, each 50-100 m apart depending on openness of the habitat, was established for each peatland. For censuses, each station was visited for a minimum of 5 minutes, during which the locations of all birds heard or seen were plotted on maps. Two observers worked each peatland, allowing comparison of plotted locations for singing birds. These observations were supplemented by a third map of calling birds made from a single poolside location during mid-June foraging observations (see below). Additional notes on locations of breeding birds were made during visits to the peatlands in May and July.

Information from all maps and notes was used to produce an estimate of the number of breeding pairs for each species in each peatland. Pairs at the peatland/upland transition were included if they were present more frequently in the peatland than the surrounding upland. Waterfowl were considered resident if they were observed on at least 2 separate dates. The small size of most peatlands surveyed meant that estimates are likely to be reasonably accurate. The major habitat type (pool, low mat, open treed mat, dense trees) used by each species was noted from these maps.

6.2.3.2 Foraging Observations

Hour-long observations were made at each peatland pool in mid-June for evidence of birds obtaining prey from the aquatic environment (including foraging within the pool itself, probing the pool edge organic substrate, or feeding on emergent aquatic insects). Blinds of mosquito netting were set up within 10 m of the pool for this purpose. Observations were qualitative, as we were interested in obtaining a list of those species relying on aquatic foods for possible more detailed studies in future. Birds feeding on flying insects were recorded only if they foraged over the pool in a manner which suggested that they were obtaining emergent aquatic insects. Additional observations of predation on aquatic organisms were noted during regular visits to peatlands.

6.2.3.3 Reproductive Ecology of Tree Swallows

Two swallow boxes were placed at the pool edge of 30 peatlands (15 in each study area) in early to mid-May. Boxes were set at approximately 1.5-2 m height above the mat or open water, with interbox distances ranging from 30 to 150 m depending on the size of the pool. Boxes were checked at one to two week intervals during May to July when swallows were breeding. Plumage colour of the female was noted for ageing (brown females are young birds, blue females older). Egg weights were estimated to the nearest one-hundredth of a gram using 5-gram spring balances, and length and breadth were measured with calipers. Nestlings were weighed (50-g balances) and measured (wing chord and tarsus lengths).

Timing of egg-laying was determined for swallow boxes with partial clutches, from knowledge that birds lay one egg per day (Paynter 1954). For other nests, hatch date was used to determine egg-laying dates by subtracting an incubation time of 15 days, which was approximately true for the few nests where incubative time was known (and in the literature: Paynter 1954, Manning 1982). Hatch date had to be estimated from size of nestlings for some of these nests and is subject to an error of two or three days plus or minus. Nestling age was calculated similarly, hatch date being calculated from laying dates for those nests where only the latter was known.

Egg volumes (V) were calculated from length (L) and breadth (B) measurements using the following formula from Hoyt (1979):

$$V = 0.507 \times L \times B^2$$

Egg density was calculated as egg weight divided by volume. A regression of egg density against number of days of incubation was calculated, excluding those eggs that failed to hatch, had already pipped, or showed any dents or fractures. This analysis allowed a crude comparison of weight loss by eggs during incubation between peatland types and study areas.

Nestling growth curves were calculated for weight, wing chord, and tarsus versus age, as in Ricklefs (1967). The NLIN curve-fitting computer program (SAS 1982) was used to give values of asymptote and growth rate that best fit the data. Swallows showed evidence of a slight weight recession after day 18 (17 days after hatch), therefore weight growth curves utilized data up to day 18. For comparison to literature values, a logistic growth curve was also calculated on weight data from day 1 to day 13 only. Three models of the growth curve, logistic, Gompertz, and von Bertalanffy (see Ricklefs 1967), were compared for best fit.

Because our visits to nests were infrequent, nestling age estimates may be in error by as much as two or three days. To circumvent this problem, an index of nestling condition was developed that did not rely on knowledge of nestling age, similar to the condition factor indices often used for fish (e.g. Ricker 1973). Since nestling weight is likely to provide a more sensitive indication of environmental conditions than wing length (e.g. O'Connor 1975, Best 1977), we used the relationship between nestling weight and wing chord length as the basis for nestling condition. This relationship was calculated using non-linear curve-fitting as described for growth curves above. Residuals about this line were used as an index of nestling condition. Nestlings with weights lower than predicted by their wing chord length were deemed to be in poor condition relative to the rest of the population. This measure assumes that nestling weight is more sensitive to environmental conditions than wing length, similar to a measure developed for seabird chicks by Ricklefs et al. (1984). This appears to be true for aerial insectivores such as swallows (Bryant 1978).

6.3 RESULTS

6.3.1 Amphibians

Adult amphibians were a conspicuous feature of the pool edge community in most peatlands. Green frogs in particular were abundant in many pools, and were observed in all but one bog at Wanapitei (Table 14). Wood frogs and spring peepers were also nearly ubiquitous at Ranger though absent from some peatlands at Wanapitei. Unlike the distribution of amphibian eggs and larvae, the presence of adult amphibians was not

Table 14: Number of peatlands where adult amphibians were observed, 1985.

	Bogs		Fens	
	Ranger	Wanapitei	Ranger	Wanapitei
Peatlands Surveyed	7	8	8	8
Notopthalmus viridescens	1		1	1
Ambystoma laterale	2		1	
Plethodon cinereus	1			
Bufo americanus	3	3	7	1
Hyla crucifer	7	5	8	4
Pseudacris triseriata		1		2
Rana sylvatica	7	6	7	4
Rana pipiens	3	4	5	6
Rana clamitans	7	7	8	8
Rana septentrionalis		1	1	6
Rana catesbeiana	1		1	5

related to pool pH, as indicated by the nearly equal presence of most species at bog pools compared to fen pools. However, mink frogs and bullfrogs (Rana catesbeiana) tended to be found in more fen pools than bog pools at Wanapitei.

Pitfalls were not efficient traps for amphibians, though wood frogs and toads were captured more frequently than other species (Table 15). Both of these species were captured in higher numbers at Ranger than at Wanapitei, though captures did not increase at higher pool pH in either study area (compare fens with bogs).

Even in habitats where amphibians are unable to breed successfully, they may play an important role in the aquatic food chain. Green frogs, mink frogs and bullfrogs inhabited the pool edge in peatlands, while toads, spring peepers, wood frogs and leopard frogs (Rana pipiens) were normally found on the Sphagnum mat. The former three species are relatively large and were observed eating odonates that had recently emerged from the pool. Aquatic invertebrates are likely to be an important food source for these amphibians.

6.3.2 Mammals

Ten species of small mammals were captured in pitfall traps, including five species of shrews (Table 16). Masked shrews (Sorex cinereus) were by far the most abundant species in both study areas, totalling 68.6% of all captures. Water shrews (Sorex palustris) are the only species of the group to eat primarily aquatic insects. This species was captured 11 times, comprising only 3.7% of all captures. In total, the insectivorous shrews comprised 75.7% of captures, while the remaining five species, all primarily vegetarians, comprised 24.3%.

Table 15: Number of amphibians caught in pitfall traps, 1985.

	Bogs		Fens	
	Ranger	Wanapitei	Ranger	Wanapitei
Total Trap-Nights	2167	2136	2531	1728
<u>Notopthalmus viridescens</u>	1			1
<u>Ambystoma laterale</u>	2		1	
<u>Plethodon cinereus</u>	1			
<u>Bufo americanus</u>	6	1	7	
<u>Rana sylvatica</u>	17	3	7	2
<u>Rana pipiens</u>		1		3
<u>Rana clamitans</u>	2	2	1	1
Total Amphibians	29	7	16	7

Table 16: Small mammals caught in pitfall traps in 1985. Abundances are given as numbers per 1000 trap-nights (see above for totals).

	Bogs		Fens	
	Ranger	Wanapitei	Ranger	Wanapitei
<u>Sorex cinereus</u>	20.8	24.3	23.7	26.6
<u>Sorex palustris</u>	0.9		0.4	4.6
<u>Sorex fumeus</u>		0.5		
<u>Sorex hoyi</u>		0.5		1.2
<u>Blarina brevicauda</u>	0.9		1.2	0.6
<u>Peromyscus maniculatus</u>				0.6
<u>Clethrionomys gapperi</u>	0.9	3.7	1.2	1.2
<u>Synaptomys cooperi</u>		0.9	0.4	0.6
<u>Microtus pennsylvanicus</u>	0.5	3.7	4.7	1.7
<u>Zapus hudsonius</u>	2.8	3.3	2.0	5.8
TOTAL Mammals	26.8	37.0	33.6	42.2

Two species which frequent open sedge and grass meadows, the meadow jumping mouse (*Zapus hudsonius*) and the meadow vole (*Microtus pennsylvanicus*) were trapped in several peatlands. Since there was a lack of suitable non-peatland habitat nearby, it is likely that these species are regular residents of central Ontario peatlands. Red-backed voles (*Clethrionomys gapperi*) were also common. The presence of this species in traps at least 100 m from the non-peatland edge also suggests residence in the peatlands. The other five species of small mammals were captured only sporadically. This included three species of small mammals which are characteristic of non-peatland forested habitat: smoky shrews *Sorex fumeus* (1 capture), short-tailed shrews *Blarina brevicauda* (6 captures), and deer mice *Peromyscus maniculatus* (1 capture). The two other species infrequently encountered were the pygmy shrew *Sorex hoyi* (3 captures) and the bog lemming *Synaptomys cooperi* (4 captures), despite apparently suitable habitat.

There were no consistent affinities by any of the species for either bog or fen habitat, despite vegetational differences, particularly in species of sedges present (see earlier section of this report dealing with vegetation). In addition, composition differences between Wanapitei and Ranger peatlands were slight. A higher rate of capture was recorded at Wanapitei (39.3 mammals/1000 trap-nights) relative to Ranger (30.4). However, more traps at Ranger showed some evidence of disturbance (17) than at Wanapitei (7), and this may have resulted in the lower capture rate at Ranger.

Several species of large mammals were known to visit the peatlands in 1985 (Table 17), though only beaver (*Castor canadensis* - 9

Table 17: Number of peatlands (out of 31) that other mammals were known to visit in 1985.

	Bogs		Fens	
	Ranger	Wanapitei	Ranger	Wanapitei
Beaver *Castor canadensis*			2	5
Muskrat *Ondatra zibethicus*			1	
Red Fox *Vulpes vulpes*		1		
Black Bear *Ursus americanus*	4	2	1	4
Mink *Mustela vison*	1		3	1
Otter *Lutra canadensis*			2	1
Moose *Alces alces*	2	5	4	1

peatlands) and muskrat (*Ondatra zibethicus* - 1 peatland) could be considered residents. Black bears (*Ursus americanus*) and moose (*Alces alces*) were recorded in the most peatlands (11 and 12 peatlands respectively), the latter often feeding on water lilies. Beaver, and the piscivorous otter (*Lutra canadensis*) and mink (*Mustela vison*), were largely restricted to fen pools.

6.3.3 Birds

6.3.3.1 Species Presence

Fourty-eight species were recorded as being resident in the thirty peatlands studied (Table 18). These species were assigned to four habitat groups based on field observations: pools, sedges plus low shrubs, *Sphagnum* mat with scattered trees, and treed peatland (Table 18).

Five species, four waterfowl and the Kingfisher (*Ceryle alcyon*), comprised the pool residents. Of these, the Ring-necked Duck (*Aythya collaris*) was the most common, though only six pairs were observed. Pool species were more abundant in fen pools than bog pools (13 pairs vs. 4). This reflects the greater total area of pools in fens (11.2 ha) compared to bogs (2.6 ha, Table 18). Wanapitei was lacking in pool residents relative to Ranger, as only 2 of 17 pairs were at Wanapitei.

Ten species were found primarily in sedge and ericaceous shrub habitat. The Yellowthroat (*Geothlypis trichas*) and Swamp Sparrow (*Melospiza georgiana*) were both very abundant in this habitat (61 and 35 pairs respectively), with the former present in slightly drier and shrubbier habitat than the latter. Three tyrranid flycatchers (Eastern

Table 18: Breeding bird pairs in 30 peatlands in 1985 (not including one large bog at Wanapitei). Habitat type most frequented by each species is given as follows: P - pool, S - sedges and low shrubs, O - open treed areas, and T - more densely treed.

Species	Habitat	Bogs		Fens		
		Ran	Wan	Ran	Wan	
N =						
American Bittern Botaurus lentiginosus	S			1		
Black Duck Anas rubripes	S		2	5		
Wood Duck Aix sponsa	P			1		
Ring-necked Duck Aythya collaris	P	1		5		
Common Goldeneye Bucephala clangula	P	1		3		
Hooded Merganser Lophodytes cucullatus	P	2		1	1	
Solitary Sandpiper Tringa solitaria	S	1	1	4	2	
Belted Kingfisher Ceryle alcyon	P			1	1	
Northern Flicker Colaptes auratus	T	1		1	2	
Yellow-bellied Sapsucker Sphyrapicus varius	T	1				
Hairy Woodpecker Picoides villosus	T				1	
Black-backed Woodpecker Picoides arcticus	T			1		
Eastern Kingbird Tyrannus tyrannus	S			1	1	
Yellow-bellied Flycatcher Empidonax flaviventris	T	8	6	2	5	14/21
Alder Flycatcher Empidonax alnorum	S			1	1	
Olive-sided Flycatcher Contopus borealis	S			1		
Tree Swallow Tachycineta bicolor *	S			2	4	
Gray Jay Perisoreus canadensis	T	3	2			
Boreal Chickadee Parus hudsonicus	T	1				
Red-breasted Nuthatch Sitta canadensis	T	1				
American Robin Turdus migratorius	O	2	1	1	3	

Table 18 (cont.)

Species	Habitat	Bogs		Fens		
		Ran	Wan	Ran	Wan	
Hermit Thrush Catharus guttatus	T	3	3	1		
Swainson's Thrush Catharus ustulatus	T	1				
Veery Catharus fuscescens	T	2				
Golden-crowned Kinglet Regulus satrapa	T	2				
Ruby-crowned Kinglet Regulus calendula	T	1				
Cedar Waxwing Bombycilla cedrorum	O	4	3	3		
Solitary Vireo Vireo solitarius	T				1	
Black-and-white Warbler Mniotilta varia	T	1	1			
Tennessee Warbler Vermivora peregrina	T	2	13		9	15 | 24
Nashville Warbler Vermivora ruficapilla	T	16	11	6	9	27 | 42
Magnolia Warbler Dendroica magnolia	T	1	1	1	1	
Cape May Warbler Dendroica tigrina	T	2	2		1	
Yellow-rumped Warbler Dendroica coronata	T	9	3	3	2	12 | 17
Blackburnian Warbler Dendroica fusca	T	1	1			
Bay-breasted Warbler Dendroica castanea	T			1		
Common Yellowthroat Geothlypis trichas	S	5	16	15	25	21 / 61
Canada Warbler Wilsonia canadensis	T	1				
Rusty Blackbird Euphagus carolinus	O				5	
Common Grackle Quiscalus quiscula	S			2		
Pine Siskin Carduelis pinus	T	1			1	
Savannah Sparrow Passerculus sandwichensis	O	4	4	4	4	
Dark-eyed Junco Junco hyemalis	T	3				
Chipping Sparrow Spizella passerina	O	1			1	

Table 18 (cont.)

Species	Habitat	Bogs Ran	Bogs Wan	Fens Ran	Fens Wan	
White-throated Sparrow <u>Zonotrichia</u> <u>albicollis</u>	T	14	19	8	13	33/54
Lincoln's Sparrow <u>Melospiza</u> <u>lincolnii</u>	O	5	5	9	7	
Swamp Sparrow <u>Melospiza</u> <u>georgiana</u>	S	2	2	15	16	4/35
Song Sparrow <u>Melospiza</u> <u>melodia</u>	O			3	2	
TOTAL PAIRS by Habitat	P	4	0	11	2	
	S	8	21	47	49	
	O	16	13	20	22	
	T	75	62	24	45	
	Total	103	96	102	118	
TOTAL AREA of each Habitat (ha)	P	1.5	1.1	4.9	6.3	
	S	1.7	3.1	16.8	13.4	
	O	3.8	4.2	4.2	3.7	
	T	9.4	6.4	1.6	4.5	
	Total	16.4	14.6	29.7	26.6	

* box-nesting swallows not included in these figures, or in Table 19.

Kingbird, Tyrannus tyrannus; Alder Flycatcher, Empidonax alnorum; Olive-sided Flycatcher, Contopus borealis) and the Tree Swallow were observed foraging most frequently in this open habitat. The Black Duck (Anas rubripes) and Solitary Sandpiper (Tringa solitaria) were most frequently observed in this plant association. The latter was the only shorebird to inhabit the peatlands. Sedges and low shrubs form the predominant vegetation of the fens studied (Table 18), so it is not surprising that birds of this habitat zone were much more common in fens (96 pairs) than in bogs (29 pairs).

The open areas of treed peatland were characterized by only seven species, of which the Lincoln's Sparrow (Melospiza lincolnii) is the most distinctive. Twenty-six pairs were spread over twenty-three peatlands, i.e. most peatlands had one pair of this species. Savannah Sparrows (Passerculus sandwichensis) were another frequently observed member of this habitat (16 pairs). With the exception of Rusty Blackbirds (Euphagus carolinus) and Song Sparrows (Melospiza melodia), both of which were found only in the fens, birds of this group showed little preference for bog vs. fen, or Wanapitei vs. Ranger.

The greatest species richness and density of birds was found in the more densely treed portions of the peatlands. Most, if not all, of these 26 species are also inhabitants of the surrounding non-peatland forests. Density estimates in these small peatlands are inflated by birds having territories comprising both peatland and non-peatland habitat. Warblers form the largest component of the spruce avifauna with ten species present. The three most characteristic species of the treed zone are White-throated Sparrows (Zonotrichia albicollis - 54 pairs), Nashville Warblers (Vermivora ruficapilla - 42 pairs) and Yellow-bellied Flycatchers (Empidonax flaviventris - 21 pairs), though Tennessee Warblers (Vermivora peregrina) are also common at Wanapitei. Abundance of these species in the peatlands reflects the extent of treed habitat present (Table 18).

6.3.3.2 Foraging Observations

A large number of birds include prey from the aquatic environment in their diets. We observed 23 species feeding on such prey near peatland pools (Table 19). This number is conservative since we could not record those species eating emergent insects that had flown away from the pool. The species are divided into five groups depending on the location and type of prey consumed. Four piscivorous species (Common Loon, Gavia immer; Great Blue Heron, Ardea herodias; American Bittern, Botaurus lentiginosus; Belted Kingfisher) were present at peatland pools, all at pools with fish. None of these species were very abundant.

Use of the pools by omnivorous and insectivorous waterfowl was more frequent, particularly in fen pools at Ranger. Black Ducks and Hooded Mergansers (Lophodytes cucullatus) were most commonly observed (11 and 10 pools respectively), followed by Common Goldeneyes Bucephala clangula (6), Ring-necked Ducks (5) and Wood Ducks Aix sponsa (2). The Solitary Sandpiper was also a frequent visitor to the edges of pools (13 pools), probing in the bottom substrate at the edges of pools for unknown prey.

Table 19: Number of peatland pools (out of 31) where birds were observed foraging on aquatic food, with presumed food given.

Species	Presumed Food	Bogs		Fens	
		Ran	Wan	Ran	Wan
Common Loon (*Gavia immer*)	fish				1
Great Blue Heron (*Ardea herodias*)	"			3	1
American Bittern (*Botaurus lentiginosus*)	"			1	
Belted Kingfisher (*Ceryle alcyon*)	"			2	2
Black Duck (*Anas rubripes*)	aquatic invertebrates	2	3	5	1
Wood Duck (*Aix sponsa*)	"		1	1	
Ring-necked Duck (*Aythya collaris*)	"	1		3	1
Common Goldeneye (*Bucephala clangula*)	"	2	1	3	
Hooded Merganser (*Lophodytes cucullatus*)	"	2	3	2	3
Solitary Sandpiper (*Tringa solitaria*)	benthic invertebrates	2	3	5	3
American Robin (*Turdus migratorius*)	emergent invertebrates	2	2		1
Veery (*Catharus fuscescens*)	"	1			
Eastern Bluebird (*Sialia sialis*)	"		1		
Common Yellowthroat (*Geothlypis trichas*)	"	1	2		4
Savannah Sparrow (*Passerculus sandwichensis*)	2		1		

Table 19: (Cont'd)

Species	Presumed Food	Bogs		Fens	
		Ran	Wan	Ran	Wan
White-throated Sparrow (*Zonotrichia albicollis*)	2	3	1	1	
Lincoln's Sparrow (*Melospiza lincolnii*)	"			1	
Swamp Sparrow (*Melospiza georgiana*)	"	1		3	4
Song Sparrow (*Melospiza melodia*)	"			1	
Eastern Kingbird (*Tyrannus tyrannus*)	flying insects			1	2
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	1				
Tree Swallow (*Tachycineta bicolor*)	"	1	1	6	5
Cedar Waxwing (*Bombycilla cedrorum*)	"		2		

A variety of passerine birds were observed gleaning insects from pool edge vegetation (Table 19). Most insects taken appeared to be teneral odonates which had just emerged from larval exuvia. Sparrows were prominant in this group, particularly the Swamp and White-throated Sparrows. This behaviour may be more common than Table 19 indicates since observations were not taken during the peak of odonate emergence in late May and early June.

A final group that relied partially on aquatic sources of food consisted of birds feeding on flying insects. Tree Swallows in particular, but also Kingbirds, Cedar Waxwings (Bombycilla cedrorum), and Yellow-bellied Flycatchers were observed taking flying insects over the pools. All of these species also fed in more terrestrial habitats. As mentioned earlier, the extent to which emergent flying insects were used by these and other birds could not easily be measured, due to the dispersal of the adult insects into terrestrial habitats.

6.3.3.3 Tree Swallow Reproduction

Thirty-eight pairs of swallows initiated nests in the swallow boxes. Of 37 females observed, all but 8 had brown plumage indicating young birds. Erection of the boxes in mid-May, when older swallows had already begun to nest, probably accounts for this high proportion of young birds. Young and old females did not differ consistently in any of the reproductive parameters measured, so female age has been ignored in further analyses.

Swallows showed evidence of intraspecific avoidance in their nest box use. At Ranger, all 15 peatlands had a single nesting box occupied before any of the second boxes became occupied. At Wanapitei the situation was similar, with only 2 of the 15 peatlands having both boxes occupied early in the season, when all peatlands had at least 1 box occupied. Five pairs occupied second boxes 2 to 5 weeks after the first box had been occupied. Peatlands where boxes were well-spaced were the most likely to have both swallow boxes occupied. Peatlands with 2 pairs of swallows had a mean interbox distance of 99 m while those with 1 pair had an interbox distance of 70 m. The closest that swallows were observed nesting was 65 m. Three boxes which were inadvertently placed within 40 m of occupied natural nests were not used by swallows. Intraspecific aggression towards visiting swallows by resident birds was frequently observed, particularly at fen sites, so it is not likely that boxes were unoccupied because of a lack of swallows.

All 7 peatlands with both boxes occupied were fens (Table 20). In part, this was because box spacing tended to be less in bogs than in fens. However, even in peatlands with a minimum of 65 m between boxes, fens were significantly more likely to have 2 breeding pairs than bogs (58% vs. 0%, $P = 0.025$, Fisher Exact Test). Selection of fens for nesting and foraging was also evident among those swallows not occupying boxes (Tables 18 and 19). There was no significant difference in occupancy of boxes at the two study areas (Table 20).

Despite the fact that boxes were erected an average of 4 days later at Wanapitei than at Ranger, there was no difference in the timing of egg-laying at the two areas. Average date of clutch initiation (date of first egg laid), excluding second pairs and renests, was 1 June in both areas. Birds nesting in fens, however, initiated 6 days earlier (29 May) than pairs in bogs (4 June; $t = 2.52$, $df = 26$, $P < 0.02$).

Table 20: Number of peatlands where one vs. two swallow boxes were occupied, by study area and peatland type.

		Boxes Occupied	
		1	2
All Peatlands:	Ranger	10	5
	Wanapitei	11	4
	Bogs	15	0
	Fens	8	7
Peatlands with Boxes > 65 m apart:			
	Ranger	5	3
	Wanapitei	6	4
	Bogs	6	0
	Fens	5	7

Mean clutch size was 5.3 eggs, ranging from 4 to 7 in 29 clutches, and showing evidence of a seasonal decline. Egg volumes averaged 1.66 cm^3 over 39 clutches, clutch means varying from 1.38 to 1.93 cm^3. Neither of these measures differed significantly between Wanapitei and Ranger, though eggs tended to be slightly smaller in bogs (1.62 cm^3) than in fens (1.69 cm^3; $t = 1.83$, $df = 37$, $P < 0.10$).

Egg density declined from a mean of 1.05 g/cm^3 during laying ($N = 35$) to 0.87 g/cm^3 on the 15th day of incubation (for 10 eggs which showed no external signs of pipping). This represents a weight decrease of approximately 17% during incubation. A linear regression of density (D) against days of incubation (I) for 221 eggs gave the equation:

$$D = 1.06 - 0.011 \times I$$

which predicts a 16% loss of egg weight over 15 days of incubation. Analysis of covariance indicated no effects of study area or type of peatland on this regression. Regressions calculated separately for Wanapitei and Ranger and for bogs and fens were very similar to the above, though eggs in bog nests tended to lose more weight over incubation (17%) than eggs in fen nests (15%).

Hatching success of eggs, calculated as the percent of eggs which were known to hatch in nests where at least one nestling was observed, was 78.5% for the study as a whole (for 149 eggs). Hatching success was lower in bogs (65.5%) than in fens (86.2%) particularly at Ranger (53.8% vs. 87.0%). All eggs hatched in only 3 of 11 nests in bogs (27%) compared to 11 of 18 nests in fens (61%). This difference is not statistically significant however (G-test, $P > 0.05$). Differences in hatching success between Ranger and Wanapitei were small (76.3% vs. 81.2% respectively).

Nestling weight growth to day 18 was best described by a Gompertz growth curve. Asymptotic mass was calculated as 23.1 g with a growth rate constant (K) of 0.292 days^{-1}. The best logistic growth curve for nestlings to 13 days of age gave an asymptote of 21.7 g and K of 0.475 days^{-1}. Tarsus growth was best described by a Gompertz curve (A = 15.2 mm, K = 0.342 days^{-1}, and wing chord by a logistic curve (A = 110.1 mm, K = 0.194 days^{-1}.

The relationship between weight (WT) and wing chord (WING) (see Figure 18) was best described by the following Von Bertalanffy equation:

$$WT/A = (1 - .967\ e^{(-.0973 \times WING)})^{3};\quad R^{2} = 0.96$$

Differences in weight from those predicted by this equation were used as an index of nestling condition.

Among nests, average nestling condition was related to the time of day nestlings were measured ($F = 4.82$, $df = 1,36$, $P < 0.05$). A regression of condition against time of day indicated an increase in weight, holding wing length constant, of approximately 1.8 g from early morning to late afternoon. For this reason, nestling condition was corrected for time of day before further analyses (residuals from the regression of condition against time of day were used as the corrected measure of condition).

Swallow nestlings at Wanapitei averaged 0.36 g heavier than nestlings at Ranger, holding wing length and time of day constant. This difference was not statistically significant for the 29 broods with

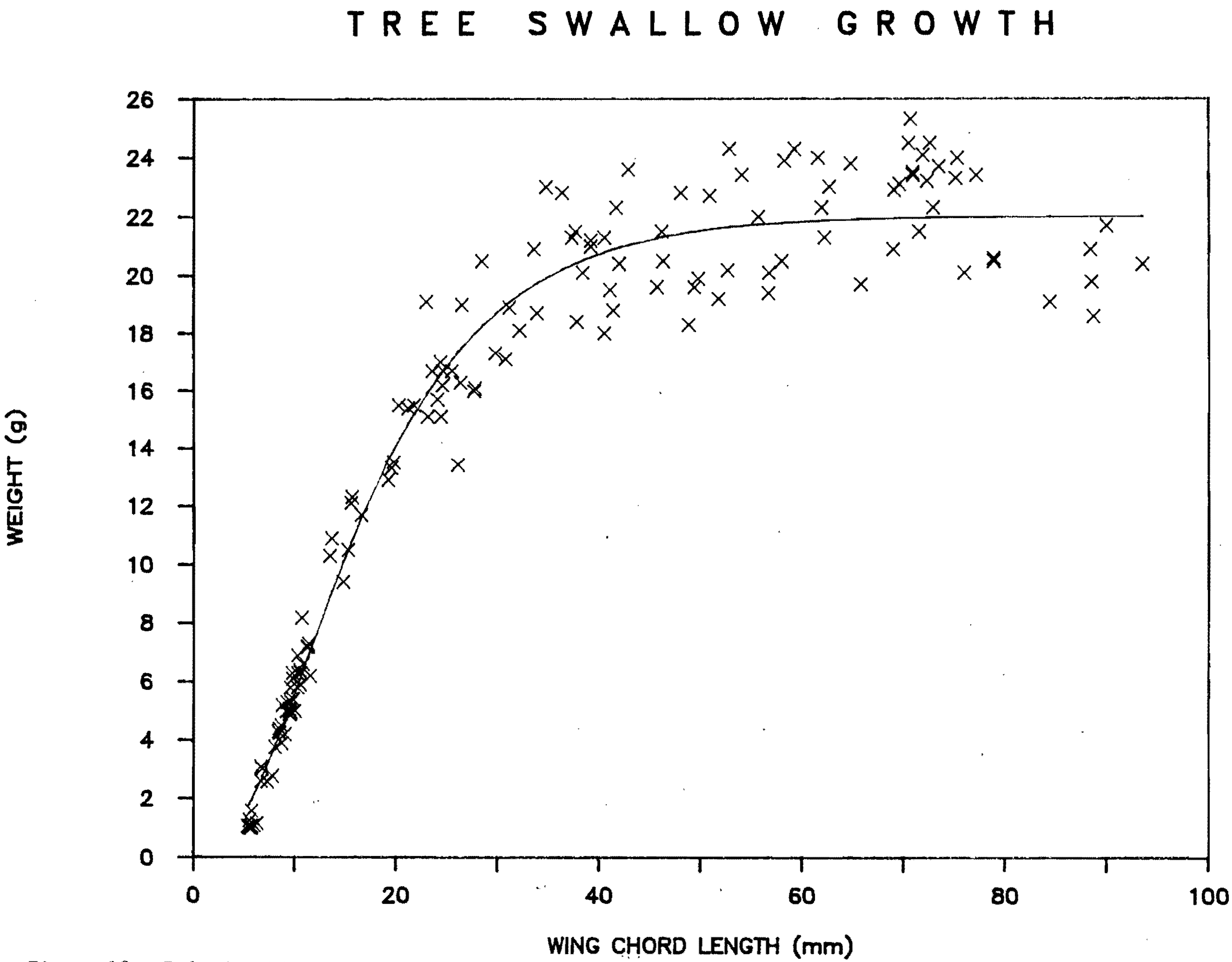


Figure 18: Relationship between weight and wing chord measurements for all Tree Swallow nestlings. Line of best fit (see text) is also plotted.

nestling measurements ($t = 0.76$). Nestlings in fens averaged 0.62 g heavier than nestlings in bogs, again a non-significant difference ($t = 1.30$, $P = 0.20$). Nestlings from broods where young were subsequently found dead tended to be in poorer condition than nestlings in broods where all young fledged (difference of 0.95 g, $t = 1.80$, $P < 0.10$).

Disturbance by large mammals, probably bears, caused 7 nests to fail. Swallows renested in 2 of these cases. Success for nests with no evidence of predation averaged 3.1 fledglings per nest, approximately 60% of eggs laid. Production did not differ between Wanapitei and Ranger (3.1 fledglings/nest at both). Success tended to be higher in fens than in bogs (3.6 vs. 2.3; $t = 1.56$, $df = 30$, $P > 0.10$) particularly when pairs nesting in second boxes were excluded from the comparison (4.2 fledglings/nest in fens, 2.3 in bogs; $t = 2.50$, $df = 25$, $P = 0.02$). In fens, pairs which nested in peatlands where swallows were already nesting had much lower success than the earlier nesting pairs (1.6 fledglings vs. 4.2, $t = 2.87$, $df = 18$, $P = 0.01$).

In summary, swallow reproduction in the two study areas was similar for all measures. Differences were observed between bog and fen habitat. More birds nested in fens, egg laying began earlier and more young were fledged. Other reproductive differences were not statistically significant, though there were tendencies for swallows in fens to lay larger eggs, which lost a smaller proportion of weight during incubation, and were more likely to hatch. Nestlings also tended to be heavier relative to wing length in fens compared to bogs.

6.4 DISCUSSION

Adult amphibians are frequently mentioned in the literature as common inhabitants of bogs and bog pools. Species which are most abundant vary with location, but usually include green frogs, wood frogs, leopard frogs, spring peepers, toads, Ambystoma salamanders, and red-spotted newts (e.g. Jewell and Brown 1929, Marshall and Buell 1955, Gosner and Black 1957, Judd 1965, Saber and Dunson 1978, IEC Beak 1983, Dale et al. 1985). With the exception of salamanders and newts, which were not observed or trapped frequently in either study area, the above list is also typical of the Wanapitei and Ranger peatlands.

Amphibians feed largely on insects and other invertebrates. Species of frogs common in the mat and treed zones of peatlands (e.g. leopard frogs, wood frogs, spring peepers) eat largely terrestrial insects (Marshall and Buell 1955). Newts, salamander larvae, and bog pool dwellers such as green frogs, mink frogs and bullfrogs probably consume a large number of aquatic invertebrates (Cook 1984). Adult amphibians are therefore an important predator in peatlands, as well as being a group sensitive to direct effects of aquatic acidity.

The use of pitfall traps to quantify small mammal populations has some limitations. In addition to the problem of predators robbing traps, pitfalls tend to be less effective at enumerating mice and voles than snap traps or live traps (Williams and Braun 1983, Boonstra and Rodd 1984). However, they are particularly efficient at catching small shrews, and catch a greater variety of small mammals than other traps (Williams and Braun 1983).

The composition of small mammals in the peatlands surveyed appears typical in most respects to literature reports. Red-backed voles, meadow voles, meadow jumping mice and bog lemmings are herbivorous species reported as common in bog habitats (Banfield 1974, Smith 1974, Wolgast 1979, IEC Beak 1983). All were trapped in the Ranger and Wanapitei study areas, though bog lemmings were scarce. The numerical predominance of masked shrews in our traps is similar to more detailed studies of shrews in Manitoba bogs and fens (Buckner 1966, Wrigley et al. 1979). Masked shrews inhabit a variety of upland and wetland habitats (van Zyll de Jong 1983). Among peatlands, they appear to prefer wetter areas where the water table is near the surface (Buckner 1966), as in fens and marshes (Wrigley et al. 1979). This likely explains their abundance near bog and fen pools in northeastern Ontario. Other shrews captured in our study were also captured in Manitoba wetlands, with the exception of the smoky shrew which is normally restricted to drier habitats (van Zyll de Jong 1983).

The water shrew is the only species caught which relies largely on an aquatic food source (Banfield 1974). It tends to prefer moving water habitats, however, and is therefore not abundant in peatlands (Wrigley et al. 1979). Several of the larger mammals present also rely on food from the aquatic environment. Water lilies and other wetland plants are favorite foods of moose, especially during the late spring and early summer (Peek et al. 1976). Otters and mink were observed foraging in peatland pools with fish, though use of less organic lakes and rivers is more typical of these species (Banfield 1974). Foods of these larger mammals is likely to be negatively affected by acidification in both clearwater and organic systems.

Peatlands tend to be depauperate of birds relative to other habitats (Erskine 1977), though bog forests and pools add species specific to these physiognomic types. Passerine communities listed in our study tend to be more diverse than those reported elsewhere (see Brewer 1967, Erskine 1977, Ewert 1982). This is a reflection of the small size and diversity of habitat in our peatlands compared to others studied. The influence of surrounding non-peatland habitat is particularly noticeable in our forested bog community.

On the other hand, species characteristic of more open parts of our peatlands tend to be the same species as reported in the literature. Waterfowl such as Ring-necked Ducks (IEC Beak 1983), Black Ducks and Goldeneyes (Elder et al. 1971, Erskine 1969, 1977) frequent larger pools such as those we studied in northeastern Ontario. Our data would add Hooded Mergansers to this list. Yellowthroats, Swamp Sparrows, Lincoln's Sparrows and Savannah Sparrows dominated the open parts of our peatlands, and these are mentioned as characteristic species of open peatland habitats by other workers (e.g. Erskine 1977, Gawn 1985). Species characteristic of well-developed fens, such as shorebirds, wrens, and rails (Erskine 1977) were conspicously absent from our Ontario peatlands, with the exception of Solitary Sandpipers. Rich fen conditions were not present in our peatlands.

Our foraging observations indicated that a large number of species rely to some extent on food from the aquatic environment. Piscivorous species would be negatively affected by pool acidification. Most birds, however, appeared to be feeding on aquatic or emergent invertebrates. Evidence presented earlier indicated that many invertebrate taxa are less abundant in very acidic pools, so that acidification could have a negative impact on a variety of insectivorous birds. This is examined in a preliminary way with Tree Swallows, which feed on flying insects.

6.4.1 Tree Swallows

Tree Swallows are readily attracted to nest boxes in peatlands, as indicated by the nesting of at least 1 pair in all 30 peatlands with boxes, and by the frequent appearance of non-breeding swallows at some sites. The low numbers of swallows nesting in natural sites is probably a reflection of a lack of suitable nest holes in most peatlands.

A difference in the abundance of nest holes could account for the presence of natural-nesting swallows in fens but not in bogs. Nevertheless, with the addition of nest boxes, swallows showed a preference for nesting in fens over bogs (only fens received second nesting pairs, and swallows nested earlier in fens than bogs). Reproductive success tended also to be lower in bogs than in fens. This could result from a difference in quality of the habitat for food gathering, though there were no differences in clutch size. Alternatively, a difference in quality of nesting pairs could explain these differences, particularly if lower quality birds were excluded from preferred habitat (fens in this case).

Our study does not provide an explanation for a preference by swallows for fens over bogs. However, fens were more open, with larger pools than bogs. Tree Swallows prefer to nest in non-wooded habitat (Harris 1979, Munro and Rounds 1985), while open water provides a food source for swallows (e.g. Turner 1983).

There is some indication from our data that peatlands are not optimal habitat for swallows. Intraspecific spacing between swallow pairs observed here was much greater than observed in studies done in upland locations (1-16 m, Muldal et al. 1985). Clutch size, initial egg weight, hatching success, and fledging success all tended to be low relative to other studies (e.g. Paynter 1954, Paganelli et al. 1974, DeSteven 1978, Manning 1982, Zach 1982, Zach and Mayoh 1982). The predominance of yearling females in this study would result in lower values of each parameter compared to studies with older females (DeSteven 1978). The predicted total weight loss of non-pipped eggs was higher in this study (15-17%) than measured weight losses for Tree Swallows (13% pre-pipping and 14% total including pipping, Manning 1982), though it was within the normal range of total weight loss for other species (14-18%, Rahn and Ar 1974, Drent 1975, Manning 1981).

Swallow nestlings also tended to show a slightly lower growth rate and weight asymptote than published values (e.g. Ricklefs 1968, Zach and Mayoh 1982, 1984). In fact, values obtained in this study (A = 21.7g, K = .475) tended to be more similar to values for swallow nestlings stressed by gamma radiation (A = 20.54, K = .463) than values for control nestlings (A = 23.51, K = .519) in a study by Zach and Mayoh (1984).

Differences between this study and others are preliminary, however, because of the young age of breeding females in the peatland population, the late erection of nest boxes, the lack of detailed data for each nest, and the probability of errors in ageing eggs and young.

There were no detectable differences in swallow reproductive parameters between Wanapitei and Ranger. This could mean that swallows are not affected by changes to the aquatic-based insect community of peatlands brought about by acid precipitation. Possibly the abundance of emergent insects available to swallows is not affected by changes in mineral acidity, or perhaps swallows are able to obtain enough terrestrial-based insects to compensate. Alternatively, the measures which we present may not be sensitive enough to illustrate differences that are present. Zach and Mayoh (1984) showed that swallow growth is negatively affected by gamma radiation, but that effects were small, thus requiring numerous accurate measures of nestling weight and age to identify. Our measure of nestling condition circumvented the problem of not knowing the age of the nestling, but is weakened by the fact that both nestling weight and wing length respond to changes in food supply (Quinney 1983). More detailed information is needed on nestling growth before study area differences can be disregarded. Knowledge of aquatic insect emergence is also needed, particularly for dipterans less than 10 mm in length which form a large part of Tree Swallow diets (Quinney and Ankney 1985).

7. SUMMARY

Thirty-one peatlands in northeastern Ontario were examined for a variety of physical, chemical and biotic parameters. Sixteen peatlands at Wanapitei, an area which has historically received a high rate of acidic deposition, were compared to 15 peatlands at Ranger, where deposition has been lower. Peatlands selected had a central pool surrounded by bog vegetation. These were divided into "bogs" and "poor fens" on the basis of hydrology, fens having visible inflows and/or outflows from the central pool.

All peatlands were bowl-type with deep, well-decomposed peat. Fens differed from bogs in having larger central pools, but study area differences were not significant. Water levels fell from mid-May to late August, then partially recovered by early November.

Chemistry differences were noted between pool and mat water samples, between fens and bogs, and between Wanapitei and Ranger. As expected, mat samples were more organic in nature than pool samples. Fens showed greater concentrations of mineral elements than bogs, though differences were not as great in mat samples as in pool samples. Wanapitei showed greater acidity, higher sulphate, higher mineral and metal concentrations in most comparisons with Ranger. These differences parallel responses by lakes to the higher acid deposition at Wanapitei. Differences were more pronounced in spring than summer, and least apparent in mat samples. An analysis of hydrogen ion concentration suggested that both mineral and organic acidity is present in bog waters. At Wanapitei, sulphate tends to be the predominant anion, whereas organic anions are more important at Ranger. These results suggest an additional influence of acid deposition on the chemistry of naturally acidic peatland waters.

Peatland vegetation appeared to be related to degree of minerotrophy of the water, and to a moisture gradient (pool edge to bog forest). Bogs were differentiated from fens by plant indicators of minerotrophy, at least at the moist end of the spectrum. Consistent differences between Wanapitei and Ranger were not obvious among the vascular plants, though sedges tended to be less prominent at Wanapitei. No direct influence of acid precipitation on mat vegetation was apparent in this preliminary study, though non-vascular plants and aquatic species were not studied.

The aquatic animal community present in peatland pools was related to pool chemistry. A cyprinid-dominated fish community was present in 12 of the peatlands, all of which had outflow streams and a pH greater than 4.8. Most invertebrate taxa fell into two groups in their response to fish and water chemistry: those that were most abundant at higher pH regardless of the distribution of fish (e.g. gastropods, leeches, amphipods), and those that responded positively to pH but only in the absence of fish (e.g. damselflies, corixids, whirligig beetles, and others). A few other taxa showed no response to pH or were more abundant in fishless pools regardless of pH. Breeding was noted for five species of amphibians in peatland pools, but successful breeding was only apparent at pH 4.45 and above. Thus most aquatic organisms appeared to be negatively affected by acidity at some point within the range of pool pHs observed (3.9 to 7.3).

Wildlife inhabiting peatlands were documented, and to a large extent they coincide with species reported in the literature. Of particular interest were those species utilizing prey from an aquatic source, as they should be susceptible to chemical changes in peatlands. Piscivorous wildlife were present though not abundant in these pools (e.g. mink, otter, kingfishers, herons). Aquatic plants also served as a minor food source for some species (moose, muskrat). Invertebrates, however, appeared to be an important wildlife food of peatland pools. Invertebrates were eaten from the pool (waterfowl, sandpipers, water shrews) and as they emerged from the pool (frogs, many species of birds). Swallows and flycatchers appeared to eat flying insects of aquatic origin. Differences between Wanapitei and Ranger in wildlife use of peatlands were minor, though use of pools by waterfowl and by some amphibian species tended to be lower at Wanapitei.

A nestbox study of Tree Swallows was initiated to measure reproductive responses to prey in peatlands. Swallows showed a preference for nesting in fens rather than bogs, and this was reflected in many measures of breeding performance (better success in fens). No study area differences were discernable, but measures taken were too crude to be able to detect small differences in nestling growth or quality of eggs.

More detailed study of wildlife responses to available prey is needed in order to assess the impact of acid precipitation on wetland-dwelling wildlife. Differences in peatland acidity that parallel levels of acid deposition, and negative responses of aquatic organisms to acidity, indicate the potential for an impact on these wildlife.

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APPENDIX 1: Means (x), standard deviations (sd), and ranges of chemical values for peatland waters shown in Tables 3-6.

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Spring (May 1985)									
K_{corr} (umho/cm)	$\bar{x}$	11.7	20.1	18.9	29.2	10.2	12.2	14.4	17.4
	sd	5.0	2.9	4.1	15.2	4.3	5.1	4.0	9.0
	min	6.7	17.4	10.9	13.4	6.6	7.2	8.6	9.7
	max	19.4	26.8	22.5	64.7	18.5	21.2	19.5	32.9
Ca (mg/l)	$\bar{x}$	0.83	2.19	1.25	3.27	0.60	0.96	0.83	1.52
	sd	0.63	0.34	0.49	2.64	0.57	0.66	0.41	1.17
	min	0.38	1.73	0.40	0.97	0.20	0.39	0.30	0.56
	max	1.75	2.92	1.93	9.42	1.85	2.46	1.37	3.69
Mg (mg/l)	$\bar{x}$	0.26	0.57	0.35	0.75	0.18	0.29	0.24	0.33
	sd	0.17	0.09	0.09	0.59	0.13	0.16	0.10	0.17
	min	0.13	0.47	0.17	0.40	0.05	0.09	0.10	0.18
	max	0.56	0.72	0.42	2.20	0.46	0.62	0.36	0.68
Na (mg/l)	$\bar{x}$	0.40	0.61	0.49	0.68	0.44	0.51	0.43	0.73
	sd	0.16	0.09	0.07	0.11	0.25	0.28	0.14	0.33
	min	0.25	0.51	0.35	0.50	0.17	0.23	0.28	0.43
	max	0.73	0.81	0.57	0.80	0.93	1.13	0.71	1.34
SiO_2 (mg/l)	$\bar{x}$	1.67	2.41	2.14	3.47	1.45	1.87	2.63	2.66
	sd	1.13	1.32	0.76	1.24	1.00	2.31	1.32	2.00
	min	0.07	0.37	1.22	1.50	0.11	0.60	1.12	0.51
	max	3.25	4.52	3.57	4.96	3.32	7.46	4.82	7.15
SO_4 (mg/l)	$\bar{x}$	3.16	4.85	7.39	8.32	1.63	1.00	3.96	3.23
	sd	1.29	1.22	2.12	2.33	1.59	0.59	2.96	3.16
	min	1.71	2.88	2.64	3.07	0.52	0.24	0.91	0.64
	max	5.08	6.62	9.40	10.5	5.15	1.72	8.09	8.63
pH	$\bar{x}$	4.52	5.79	4.13	5.54	4.42	4.82	4.00	4.72
	sd	0.21	0.46	0.11	0.89	0.15	0.48	0.05	0.66
	min	4.30	5.18	3.97	4.29	4.30	4.26	3.94	4.14
	max	4.91	6.43	4.29	7.28	4.75	5.63	4.09	6.03
Alk. (ueq/l)	$\bar{x}$	0.0	37.9	0.0	72.8	3.5	6.6	0.0	12.1
	sd	0.0	33.4	0.0	167.	9.3	15.3	0.0	26.7
	min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	max	0.0	81.6	0.0	481.	24.6	43.6	0.0	75.4

APPENDIX 1 (cont.)

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Spring (cont.)									
Al (ug/l)	$\bar{x}$	81.	119.	176.	129.	111.	73.	123.	83.
	sd	52.	52.	72.	78.	56.	44.	32.	21.
	min	43.	55.	82.	31.	24.	45.	89.	58.
	max	169.	213.	270.	228.	172.	180.	170.	123.
Mn (ug/l)	$\bar{x}$	21.0	12.9	44.5	47.0	13.0	13.9	20.7	28.9
	sd	9.5	4.6	20.7	28.8	5.3	8.6	13.5	16.1
	min	12.4	5.7	12.6	4.5	7.3	7.6	5.0	12.2
	max	41.7	17.3	75.7	92.5	20.0	28.2	40.9	55.9
Colour (hazen)	$\bar{x}$	73	58	79	48	119	131	150	154
	sd	36	13	33	21	40	26	46	65
	min	40	35	55	20	55	100	100	60
	max	150	70	150	75	150	150	200	250
TDC (mg/l)	$\bar{x}$	13.5	12.6	17.2	11.7	22.7	23.1	35.0	31.3
	sd	2.4	1.6	6.4	2.5	7.8	4.1	11.2	13.2
	min	10.9	10.3	13.0	8.3	12.0	17.7	18.5	12.9
	max	18.0	15.2	32.2	15.5	35.6	29.6	51.7	55.0
DOC (mg/l)	$\bar{x}$	11.8	10.4	15.4	9.6	19.3	20.1	28.9	26.5
	sd	2.0	1.6	5.7	1.8	6.8	4.0	10.7	11.2
	min	9.3	8.1	11.3	7.2	10.4	15.2	16.4	9.9
	max	15.4	12.7	28.9	12.1	31.0	25.5	43.2	45.8
A^- (ueq/l)	$\bar{x}$	78.	92.	87.	79.	121.	143.	155.	174.
	sd	19.	14.	29.	16.	41.	24.	58.	58.
	min	58.	76.	65.	57.	66.	108.	89.	91.
	max	115.	119.	155.	100.	194.	183.	229.	266.
DIC (mg/l)	$\bar{x}$	1.7	2.1	1.9	2.1	3.5	3.1	6.1	4.7
	sd	0.4	0.7	0.8	1.8	1.0	1.6	5.2	2.3
	min	1.3	1.4	0.7	1.0	1.6	0.0	1.5	2.1
	max	2.6	3.7	3.3	6.5	4.6	4.6	17.8	9.2
PO_4 (ug/l)	$\bar{x}$	2.15	1.13	2.01	1.26	1.96	2.33	3.42	3.12
	sd	1.36	0.32	1.28	0.33	0.70	0.56	1.79	2.84
	min	1.16	0.56	0.93	0.65	0.85	1.24	0.97	0.00
	max	4.97	1.42	4.55	1.54	2.95	2.97	5.89	8.95

APPENDIX 1 (cont.)

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Spring (cont.)									
Cu (ug/l)	$\bar{x}$	–	–	2.8	–	2.9	–	4.7	9.7
	sd	–	–	1.4	–	3.2	–	1.6	7.0
	min	0	0	1.5	< 1	0	< 1	2.7	3.1
	max	< 1	< 1	6.1	7.3	9.5	2.7	7.7	24.3
Fe (ug/l)	$\bar{x}$	106.	84.	219.	225.	133.	150.	444.	859.
	sd	40.	36.	90.	138.	85.	94.	155.	680.
	min	63.	30.	102.	52.	29.	57.	200.	190.
	max	160.	129.	400.	460.	285.	350.	630.	2310
Pb (ug/l)	$\bar{x}$	–	–	–	–	–	–	–	–
	sd	–	–	–	–	–	–	–	–
	min	< 1	< 1	< 1	0	< 1	< 1	< 1	0
	max	1.4	1.9	2.7	1.0	3.4	1.7	2.9	4.0
Zn (ug/l)	$\bar{x}$	7.3	4.3	7.9	8.0	21.0	21.9	18.9	26.4
	sd	2.9	1.3	2.2	5.0	7.7	10.4	3.7	12.8
	min	3.4	2.7	4.9	2.2	11.6	11.3	15.5	14.1
	max	12.9	6.6	11.6	15.9	30.0	40.0	26.2	50.0
Cl (mg/l)	$\bar{x}$	0.20	0.28	0.15	0.21	0.55	0.64	0.38	0.59
	sd	0.07	0.09	0.03	0.03	0.40	0.54	0.13	0.24
	min	0.11	0.18	0.10	0.15	0.27	0.16	0.25	0.33
	max	0.30	0.48	0.18	0.28	1.41	1.76	0.65	1.01
K (mg/l)	$\bar{x}$	0.27	0.27	0.15	0.28	0.43	0.39	0.17	0.51
	sd	0.13	0.09	0.09	0.08	0.32	0.17	0.11	0.41
	min	0.15	0.18	0.03	0.20	0.10	0.12	0.08	0.14
	max	0.51	0.41	0.32	0.44	1.02	0.67	0.40	1.35
Ni (ug/l)	$\bar{x}$	–	–	9.6	9.1	–	–	10.5	10.5
	sd	–	–	1.8	5.5	–	–	2.8	4.1
	min	0	< 1	6.4	3.3	< 1	0	8.0	6.8
	max	1.0	< 1	11.5	19.5	3.3	1.0	16.8	17.7
NO_2NO_3 (ug/l)	$\bar{x}$	11.7	17.1	7.4	9.9	11.1	7.4	7.5	4.4
	sd	6.4	9.5	3.0	4.3	3.0	3.3	6.3	11.5
	min	4.8	6.0	4.6	5.5	7.1	2.7	0.0	0.0
	max	20.3	31.6	14.1	19.2	16.8	12.1	18.0	32.7

APPENDIX 1 (cont.)

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Summer (August 1985)									
NH_3 (ug/l)	$\bar{x}$	43.6	39.7	30.1	20.5	53.2	43.0	28.5	35.8
	sd	19.4	15.4	31.6	10.7	29.5	14.6	14.2	14.1
	min	23.4	24.6	9.6	9.3	27.7	21.7	14.7	15.8
	max	65.9	66.3	104.	42.6	113.	66.4	60.5	54.7
K_{corr} (umho/cm)	$\bar{x}$	9.1	23.6	12.1	25.8	10.9	17.5	17.8	18.2
	sd	5.6	6.9	3.6	15.3	3.4	4.4	10.6	13.3
	min	4.3	17.2	6.5	10.2	5.3	11.8	-0.7	-1.5
	max	17.5	35.4	16.1	60.3	15.4	24.2	35.2	37.6
Ca (mg/l)	$\bar{x}$	0.79	3.02	1.21	3.15	0.75	1.28	1.59	1.78
	sd	0.63	0.98	0.50	2.57	0.23	0.70	0.87	1.44
	min	0.29	2.08	0.46	0.82	0.39	0.44	0.59	0.73
	max	1.87	4.92	1.77	8.92	1.13	2.51	3.02	5.15
Mg (mg/l)	$\bar{x}$	0.26	0.79	0.31	0.72	0.26	0.55	0.39	0.39
	sd	0.19	0.26	0.10	0.62	0.06	0.30	0.19	0.23
	min	0.10	0.45	0.15	0.38	0.19	0.18	0.13	0.13
	max	0.60	1.17	0.40	2.25	0.33	1.09	0.68	0.74
Na (mg/l)	$\bar{x}$	0.28	0.68	0.43	0.66	0.33	0.46	0.62	0.63
	sd	0.15	0.17	0.11	0.12	0.06	0.34	0.17	0.26
	min	0.15	0.47	0.29	0.50	0.23	0.12	0.42	0.37
	max	0.53	1.01	0.57	0.77	0.41	0.71	0.86	1.15
SiO_2 (mg/l)	$\bar{x}$	0.21	2.11	0.65	1.47	0.81	2.17	1.44	2.42
	sd	0.33	1.45	0.87	1.20	0.25	1.99	0.35	1.42
	min	0.00	0.46	0.07	0.46	0.32	0.50	0.83	1.28
	max	0.71	4.78	2.69	3.78	1.13	6.30	1.77	5.30
SO_4 (mg/l)	$\bar{x}$	2.87	3.46	5.98	6.24	3.26	4.56	6.35	6.67
	sd	1.57	2.14	2.37	2.00	1.69	3.88	3.60	3.75
	min	1.27	1.16	1.97	2.71	1.61	0.46	1.88	2.97
	max	5.79	7.94	9.17	8.70	5.61	11.1	11.7	11.9
pH	$\bar{x}$	4.50	6.24	4.08	5.46	3.87	4.06	3.91	3.99
	sd	0.33	0.29	0.13	0.88	0.12	0.26	0.23	0.41
	min	4.30	5.93	3.92	4.23	3.68	3.73	3.67	3.62
	max	5.23	6.67	4.27	7.11	4.00	4.45	4.16	4.96

APPENDIX 1 (cont.)

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Summer (cont.)									
Alk. (ueq/l)	$\bar{x}$	0.0	78.4	0.0	88.5	0.0	0.0	0.0	0.0
	sd	0.0	85.1	0.0	160.	0.0	0.0	0.0	0.0
	min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	max	0.0	259.	0.0	460.	0.0	0.0	0.0	0.0
Colour (hazen)	$\bar{x}$	69	96	125	75	294	300	432	430
	sd	19	35	111	37	99	143	193	188
	min	50	55	50	50	160	100	270	180
	max	110	140	360	160	480	480	880	640
TDC (mg/l)	$\bar{x}$	14.0	17.7	18.6	13.7	36.7	35.1	49.7	50.7
	sd	2.0	5.0	10.2	4.1	4.5	10.7	11.5	15.9
	min	10.6	11.7	9.0	7.6	30.4	22.5	32.8	34.8
	max	17.0	24.6	35.8	19.5	43.6	53.4	64.0	78.0
DOC (mg/l)	$\bar{x}$	13.0	15.5	17.6	11.4	34.2	33.7	46.6	48.4
	sd	2.0	4.2	9.8	3.6	5.9	10.5	10.8	15.1
	min	9.6	10.3	8.3	4.9	24.3	21.6	30.7	33.5
	max	15.8	20.4	33.8	17.4	42.1	51.9	60.9	74.2
A^- (ueq/l)	$\bar{x}$	86.	146.	97.	93.	173.	184.	251.	254.
	sd	21.	41.	51.	32.	27.	51.	62.	70.
	min	60.	94.	45.	39.	126.	103.	176.	183.
	max	128.	196.	175.	129.	203.	253.	345.	370.
DIC (mg/l)	$\bar{x}$	1.0	2.1	1.0	2.2	2.5	1.4	3.2	2.3
	sd	0.2	1.1	0.6	1.6	2.4	0.5	1.6	1.1
	min	0.8	1.1	0.3	0.6	0.7	0.4	1.7	0.7
	max	1.4	4.2	1.9	5.8	7.7	1.8	6.4	3.8
PO_4 (ug/l)	$\bar{x}$	1.93	2.45	2.10	1.72	2.68	2.81	3.83	4.91
	sd	0.40	0.91	1.36	0.66	0.43	0.74	0.82	2.28
	min	1.38	1.31	0.99	1.14	1.80	1.67	2.79	2.07
	max	2.66	4.06	4.89	3.10	3.04	3.89	4.75	9.38
Cl (mg/l)	$\bar{x}$	0.12	0.37	0.26	0.33	0.49	0.83	0.93	0.96
	sd	0.05	0.26	0.14	0.08	0.11	0.47	0.46	0.51
	min	0.06	0.05	0.14	0.18	0.37	0.22	0.45	0.36
	max	0.18	0.87	0.59	0.44	0.70	1.65	1.57	1.81

APPENDIX 1 (cont.)

		Pool Samples				Mat Samples			
		Ranger		Wanapitei		Ranger		Wanapitei	
		Bog n=7	Fen n=8	Bog n=8	Fen n=8	Bog n=7	Fen n=8	Bog n=8	Fen n=8
Summer (cont.)									
K (mg/l)	$\bar{x}$	0.08	0.24	0.07	0.12	1.00	1.27	1.44	1.63
	sd	0.08	0.11	0.08	0.07	0.48	0.81	1.07	1.40
	min	0.00	0.11	0.00	0.04	0.41	0.29	0.52	0.60
	max	0.20	0.41	0.23	0.22	1.85	2.40	3.83	4.79
NO_2NO_3 (ug/l)	$\bar{x}$	1.0	4.0	18.3	14.9	5.1	4.9	31.1	41.1
	sd	1.3	3.6	32.5	9.0	5.1	2.5	35.5	29.1
	min	0.0	1.0	0.0	6.0	1.0	3.0	9.0	15.0
	max	3.0	12.0	98.0	35.0	16.0	11.0	115.	110.
NH_3 (ug/l)	$\bar{x}$	76.	85.	155.	167.	135.	165.	251.	287.
	sd	35.	38.	21.	58.	41.	32.	76.	81.
	min	27.	39.	124.	110.	97.	106.	141.	196.
	max	115.	133.	180.	291.	211.	211.	382.	451.

APPENDIX 2: Detailed list of invertebrate taxa identified to date from sweep net and minnow trap samples, with notes regarding distribution and relative abundance.

INSECTA

Diptera (larvae):

Chironomidae - common in most pools, more abundant in fishless pools than in pools with fish.

Chaoboridae - *Chaoborus americanus* - abundant in fishless pools, absent from pools with fish.

Ceratopogonidae - occasionally caught in dip net samples.

Culicidae - *Aedes* - present in 1 bog pool at Ranger.

Tabanidae - present in 3 pools.

Stratiomyidae - *Stratiomys* - present in 1 bog pool at Wanapitei.

Hemiptera (adults + larvae):

Notonectidae:

Notonecta undulata - abundant in fishless pools, occasionally caught in pools with fish.

N. insulata - present in 4 bog pools.

N. borealis - present in 4 fishless pools.

Buenoa - present in several pools, including pools with fish; most abundant in fishless pools with highest pH.
- includes *B. confusa* (mainly in fishless pools) and *B. limnocastoris* (in 3 pools with fish).

Corixidae:

Hesperocorixa kennicotti - present in 1 pool with fish at Wanapitei.

H. lobata, *H. atopodonta*, *H. minorella*, *H. vulgaris*, *H. scabricula* - present only in fishless pools; latter 2 species only seen at Wanapitei.

Sigara compressoidea - common only in pools with fish.

S. dolabra - common only in fishless pools.

S. mackinacensis - present in most pools with fish, in 1 fishless pool.

S. signata - present in several fishless pools, in 1 pool with fish.

S. penniensis - present in 7 pools.

S. douglasensis - present in 6 pools.

S. defecta - present in 2 bog pools at Ranger.

S. bicoloripennis - present in 1 bog pool at Wanapitei.

S. solensis - present in 1 fen pool with fish at Wanapitei.

Callicorixa audeni - present in 1 bog pool at Ranger.

Gerridae:

Gerris buenoi - present at most bog pools, infrequent at pools with fish.

G. comatus - present only at fishless pools.

Rheumatobates rileyi - present at 1 bog pool at Wanapitei.

Limnoporus dissortis - present at 1 fen pool at Ranger.

Nepidae - *Ranatra* - present in several pools, most abundant in fishless pools with highest pH.

Belostomatidae - *Lethocerus americanus* - common in most pools, caught in minnow traps.

Trichoptera (larvae):

Polycentropodidae - *Polycentropus* - common in fishless pools, present in 1 pool with fish.

Phryganeidae:

Banksiola - common in fishless pools at Wanapitei, present in 2 pools with fish (1 at Ranger).

Agrypnia - present in 3 pools.

Phryganea - present in 1 bog pool at Wanapitei.

Ptilostomis - present in 1 bog pool at Wanapitei.

Limnephilidae:

<u>Anabolia</u> - present in 7 pools.

<u>Limnephilus</u> - present in 6 pools with pH 4.9 or above.

<u>Nemotaulius</u> - present in 1 pool at Wanapitei with pH 7.0.

<u>Coleoptera (adults + larvae)</u>:

Dytiscidae:

<u>Graphoderus</u> <u>liberus</u> - common in fishless pools, absent from pools with fish, most abundant in higher pH fishless pools.

<u>G.</u> <u>fasciatocollis</u> - present only in fishless pools, caught only in minnow traps.

<u>Coptotomus</u> <u>interrogatus</u> - common in fishless pools, absent from pools with fish.

<u>Acilius</u> <u>semisulcatus</u> - present in 5 fishless pools.

<u>Hydroporus</u> - present in 3 fishless pools at Wanapitei.

<u>Laccophilus</u> - present in 2 fishless pools.

<u>Rhantus</u> - present in 2 fishless pools.

<u>Agabus</u> - present in 3 pools including 1 with fish.

<u>Dytiscus</u> <u>verticalis</u> - present in several pools, including pools with fish.

<u>Dytiscus</u> <u>harrisii</u> - present in 2 bog pools.

<u>Dytiscus</u> <u>dauricus</u> - present in 1 bog pool at Ranger.

Gyrinidae:

<u>Gyrinus</u> - present in 7 pools, including 2 with fish.

<u>Dineutes</u> - present in 3 fishless pools.

Haliplidae - <u>Haliplus</u> - present in 4 pools, including 1 with fish.

Hydrophilidae:

<u>Tropisternus</u> - present in 4 pools, including 1 with fish.

<u>Enochrus</u> <u>cinctus</u> - present in one bog pool.

Odonata (larvae):

Libellulidae (mostly *Leucorrhinia*) - present to abundant in all pools, most abundant in fishless pools.

Corduliidae - present in most pools, more common in fen pools than bog pools.

Aeshnidae - common in most pools, most abundant in fishless pools with higher pH.

Gomphidae - present in 4 fen pools with fish, absent from fishless pools.

Coenagrionidae - present in most pools, most abundant in fishless pools of higher pH.

Lestidae - *Lestes* - present in fishless pools with higher pH, and in 1 pool with fish.

Ephemeroptera (larvae):

Caenidae - present in 1 fen pool at Wanapitei (pH 5.9).

Leptophlebiidae - present in 1 fen pool at Wanapitei (pH 4.9).

Siphlonuridae (including *Siphlonurus*) - present in 3 pools, pH's 4.9, 5.9, 7.0.

Lepidoptera (larvae) - Pyralidae - *Nymphula* - present in 1 bog pool at Ranger.

MOLLUSCA

Gastropoda: *Helisoma anceps* - present in 3 pools; pH's 5.9, 6.3, 7.0.

Physagyrina - present in 1 pool at Wanapitei with pH 7.0.

Gyraulus - present in 1 pool at Ranger with pH 6.2 (damaged specimen, identification not positive).

CRUSTACEA

Amphipoda: *Crangonyx richmondensis* - present in 5 fen pools with pH > 5.5

Hyallela azteca - present in 2 fen pools; pH's 6.3, 7.0.

Other invertebrates that have not been further examined include: Pelecypoda-Sphaeriidae, Oligochaeta, Hirudinea, Acari, Cladocera, Copepoda, and Decapoda.

APPENDIX 3. Locations of study wetlands, given as U.T.M. grid references from 1:50,000 maps (Dept. Energy, Mines and Resources)

	Wetland #	Map #	Grid Reference
Ranger			
Bog Pools	RB8	41 J/13	938 917
	RB17	41 O/4	063 148
	RB33	"	959 096
	RB34	"	877 176
	RB35	"	988 126
	RB37	"	903 222
	RB120	"	991 114
Fen Pools	RB2	41 J/12	745 795
	RB9	41 J/13	950 899
	RB12	41 O/4	988 111
	RB15	"	022 108
	RB16	"	066 143
	RB18	"	984 177
	RB30	"	976 107
	RB38	"	043 165
Wanapitei			
Bog Pools	WB13	41 I/15	181 015
	WB19	"	066 909
	WB25	"	243 023
	WB33	"	174 996
	WB34	"	365 968
	WB36	"	157 922
	WB40	"	287 941
	WB310	41 P/2	202 057
Fen Pools	WB1	41 I/15	093 874
	WB4	"	114 857
	WB5	"	057 910
	WB6	"	061 906
	WB7	"	055 921
	WB9	"	165 916
	WB31	41 P/2	200 056
	WB38	41 I/15	136 930