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UNIVERSITY OF ALBERTA

THE WETLANDS OF ELK ISLAND NATIONAL PARK: VEGETATION, DEVELOPMENT, AND CHEMISTRY

BY

BARBARA NICHOLSON

A thesis submitted to the Faculty of Graduate Studies and
Research in partial fulfillment of the requirements for the
degree of DOCTOR OF PHILOSOPHY

IN

PEATLAND ECOLOGY

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA
Spring 1993

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Steve C. Zoltai

Dr. Paul. Glaser

December 3, 1992.

To all who strive and aspire.

To my son Trevor, in hopes that someday he will reach beyond himself to achieve a higher goal and accomplish his life's greatest ambition.

To Dale, the man whom has taught, guided, listen, shared and cared. Thanks for showing me how, and generally devoting nine years of your life to see the successful completion of this thesis.

To Scott, for giving me the incentive and ambition to begin and finish this project.

Abstract

A vegetation survey of the wetlands of Elk Island National Park (EINP) resulted in the recognition of thirteen TWINSPAN vegetation groups ranging from saline marshes to forested bogs. Vegetation is predominantly controlled by water flow and cation gradients. Nutrient (nitrogen, phosphorus) content of the surface waters is not as important in determining species composition. The surface water of marshes, swamps, and moderate-rich fens are circumneutral in pH and high in calcium, magnesium, and sodium. Poor fens and bogs are acidic, with lower mineral contents. Elevation, number of inlet and outlet streams, water level, and hummock height all contribute to the diversity and composition of species in these wetlands. All wetlands at EINP have formed in small shallow basins. Two successional pathways of peatland evolution were identified from peat profiles; Aquatic - Rich fen - Poor fen - Bog and Aquatic - Marsh - Swamp. Autogenic factors drive the successional pathway. Autogenic changes evident in the developmental profiles are: 1) elevation of the peat surface from the local water table 2) acidification of the environment, 3) oligotrophism. Edaphic factors, not climate, control the rate and direction of successional changes. Severe water table fluctuations prevent the establishment of *Sphagnum* and the development of bog vegetation. Climate has affected peatland development of the park by 1) delaying peat initiation until after about 6700 yBP, 2) expanding the peat basins during a wetter period following 6720 yBP, 3) limiting peat formation to small terrestrialized basins and 4) delaying peatland succession compared to more northerly peatlands. Physical and chemical parameters measured in the peat profiles indicate that minerals were abundant during early aquatic stages. Oligotrophism and elevation of the peat surface is a process which is occurring in all wetland types. Results of the discriminant analysis on macrofossil peat tyes indicates that it is possible to identify peat types based upon chemical and physical characteristics alone. Sediments formed under aquatic conditions have high ash and bulk density values (> 20%, > 0.15 g/cm^3), and high elemental contents. Marsh and swamp peats contain less than 20% ash and less than 0.15

g/cm^3 bulk density values, but greater than 1×10^4 mg/Kg calcium. Fen peats contain less than 12% ash and 1×10^4 mg/Kg of calcium, while bog peats contain 6% ash and less than 5×10^3 mg/Kg calcium.

Acknowledgements

I would like to thank the management and staff at Elk Island National Park for their outstanding support and assistance, particularly Peter Deering and Al Westhaver. I am indebted to Dale Vitt, Michael Ashby, Linda Halsey, Randy Craik, Dennis Gignac, Christopher Miller, and Scott Trueman for their physical and academic contributions. Assistance was also provided by summer students of the University of Alberta's WISEST program. Funding for this project was provided by Supply and Services Canada Contract No. K3482-8-0122/01-SS.

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INTRODUCTION

Climate change that has occurred since the retreat of the Laurentide Ice Sheet has had a significant impact on the vegetation and lakes of Alberta. Paleolimnological records indicate that a warm dry period reduced lake levels in central Alberta from between 7000 to 3000 years before present (yBP) (Forbes and Hickman 1981, Hickman and Klarer 1981, Hickman 1987). This prolonged and severe drought lowered water levels from eight to eighteen meters in the deeper lakes and dried shallower ponds to salty pans (Anderson *et al.* 1987). Pollen records from central Alberta indicate that this period of increased warmth and decreased precipitation reached its maximum at 5500 to 6000 yBP (Lichti-Federovich 1970). Vegetation in the area surrounding Elk Island National Park (EINP) prior to 4500 yBP was an open grassland with high fire frequency (Vance 1979, Vance *et al.* 1983). With increased precipitation and lower temperatures, the grassland vegetation became covered by a poplar, spruce and birch canopy by 3000 yBP. Pollen records from Clearwater bog located in the southern boreal forest of Manitoba (53°59'N, 101°12'W) indicate that a maximum expansion of prairie grassland occurred in this area between 6,700-4,200 yBP. Spruce forest returned after 4,200 yBP (Nichols 1969).

Climate controls the accumulation of peat material. Basal dates of organic sediments in 52 fens located across west-central Canada are older than 6000 yBP in a zone north of the 54°30'N latitude and younger south of this zone (Zoltai and Vitt 1990). This is attributed to the warm, dry, early Holocene climate causing seasonal droughts and preventing the establishment of peat-forming fen vegetation. As the climate cooled, fens expanded southwards. Vance (1979) and Vance *et al.* (1983) found that peat development in and surrounding Elk Island National Park did not begin until after 4180 yBP. Climate controls not only the time at which peat begins to accumulate, but the process by which peatlands are initiated.

Peatlands are formed through two processes. The first is termed terrestrialization, an infilling process where small open basins of water become progressively infilled by sediments that accumulate on the bottom, and rafts of vegetation that extend from the lake edge (Kratz and DeWitt 1986). Paludification is a process by which mesic sites become increasingly hydric and are either gradually encroached upon by neighboring peatlands (Futyma and Miller 1986, Kubiw *et al.* 1989, Miller and Futyma 1987, Zoltai and Johnson 1985) or develops conditions suitable for the accumulation of sedge and/or moss peats (Sjörs 1961). Expansion of peatlands via paludification has been documented in Alberta by Kubiw (1987), Kubiw *et al.* (1989), Nicholson (1989), Nicholson and Vitt (1990); in Minnesota by Glaser *et al.* (1990), Griffin (1977), Heinselman (1963), (1970), and Janssens *et al.* 1992; in Labrador by Foster and King (1984); and in Alaska by Klinger *et al.* (1990). Peat development via paludification is more dependent upon regional climatic conditions to maintain hydric conditions than terrestrializing lake basins, which have their own water source. As climatic conditions become more arid, peatland development becomes limited to terrestrialized basins.

At present, Elk Island National Park is situated in a southerly extension of the mixedwood section of the Boreal Forest region (Rowe 1972). A rise in the local bedrock topography of the Cooking Lake moraine has created a corresponding change in climate (cooler, moister). This area is characterized by a mixture of *Populus tremuloides* Michx,, *Populus balsamifera* L., *Betula papyrifera* Marsh., *Picea mariana* (Mill,)BSP., *Picea glauca* (Moench) Voss, *Abies balsamea* (L.) Mill. and *Pinus banksiana* Lamb. Areas immediately adjacent to the moraine are located in the aspen grove or parkland zone (Bird 1961, Rowe 1972), which is considered to be a wide transition zone or ecotone (Rowe 1972, Vance 1979, Vance *et al.* 1983). In this transition, vegetation of the great plains grassland and the boreal forest mix in a complex mosaic. *Populus tremuloides* is the dominant forest cover with sporadic occurrence of *Populus balsamifera* and *Betula papyrifera*. Published maps that identify the southern limit of coniferous trees on the Canadian prairies (Zoltai 1975), place Elk Island just inside the southern limit for several coniferous species, namely, white spruce (*Picea glauca*), black spruce (*Picea mariana*), tamarack (*Larix laricina* (Du Roi) K. Koch), and jackpine (*Pinus banksiana*). The position of these vegetation boundaries and transition zones is predominantly controlled by climate.

Wetland terminology and classification

The term wetland can be defined in many ways (Millar 1976, Mitsch and Gosselink 1986, Zoltai 1988, Zoltai *et al.* 1975). A common concept that occurs in all is the presence of a water table at or near the surface for a sufficient length of time to promote the growth of hydrophilic vegetation. Peatlands are a subgroup of wetlands that are characterized by the accumulation of peat or organic soil. The

Canadian System of Soil Classification (Canada Soil Survey Committee 1978) requires 60 cm of peat accumulation if the peat is fibric, 40 cm if it is mesic or humic, and 10 cm if underlain by bedrock. Many of the terms used to describe different wetland types originated in Europe and are now being used in Canada and the United States. Some terms (swamp, marsh, fen, bog) are used to describe very specific wetland types (Crum 1988, Mitsch and Gosselink 1986, Zoltai 1988). Others are less definitive in nature (mire, muskeg, moor, bottomland, peatland) and are used to describe any peat accumulating wetland. Terms such as ombrotrophic and minerotrophic are used to identify plant communities within the peatland. Ombrotrophic defines plant communities that are "rain fed", or receive water and nutrients from precipitation only (Damman 1986, Malmer 1962 and 1985, Zoltai 1988), and minerotrophic defines plant communities that receive water which has been in contact with the mineral soil. Another set of peatland terminology describes the water source in combination with the basin configuration. Limnogenous peatlands are riparian peatlands (located adjacent to a river or lake), and the water source of the peatland is dependent upon the lake or stream (Damman 1986, Malmer 1985, Zoltai 1988). Topogenous peatlands are isolated depressional basins that have perched water tables. Water source for these peatlands is rain and surface runoff. Ombrogenous bogs, are peatlands that receive nutrient poor water from precipitation only. They can exist in depressional basins or along slopes.

Peat is generally defined as organic residues of incomplete decomposition under water-saturated conditions (National Wetlands

Working Group 1988). The Canadian System of Soil Classification has defined peat physically as soils containing 17% or more organic C or 30% or more organic matter (Canada Soil Survey Committee, Subcommitte on Soil Classification 1978). Peats can be subdivided into three types based upon where it is formed in relation to the water table. Peats which formed below the water table are termed limnic peats; those formed between high water table levels and low water table levels are telmatic peats; those formed above the high water table level are terrestric peats (Faegri and Iversen 1989).

In the past, wetland classification systems have been designed to inventory waterfowl habitats. Particularly important, have been classification systems that are suitable for large scale aerial surveys and mapping. More recently, wetland classification systems have placed greater emphasis on vegetation, hydrology, and water chemistry parameters. In western Canada, there have been two notable wetland classification systems, J. B. Millar's (1976) system for western Canada, and the Canadian Wetland Classification System (Zoltai *et al.* 1975). In Millar's system, wetlands are restricted to marshes and shallow open waters; he excludes bogs and fens from his system. Millar segregates eight wetland types on vegetation characteristics, and qualifies his groupings by the length of time each group has been flooded. Millar further attempts to relate his classification to water chemistry parameters, namely salinity. The following is a summary of Millar's (1976) wetland classification.

1) **Wet Meadow**- an area flooded for 3-4 weeks at a time, and occupied by low stature grasses and sedges with a variety of forbes. In the aspen parkland, willows characteristically dominate.

2) **Shallow Marsh**- an area where flooding lasts until July or early August. Vegetation dominated by intermediate height grasses, sedges, and forbes.

3) **Deep Emergent Marsh**- an area that is inundated from spring to late summer or fall. Only five species predominate and these are grass like plants, which are taller than the vegetation of the shallow marsh zone.

4) **Transitional Open Water Wetland**- an unstable wetland that develops following flooding of emergent vegetation. Vegetation variable, consisting of *Lemna*, aquatic mosses, and liverworts.

5) **Open Water Marsh**- a wetland, which has less than 75% of it's diameter as shallow open water, with rooted or floating aquatic plants.

6) **Shallow Open Water Wetland**- a wetland which has greater than 75% of it's diameter as shallow open water with aquatic plants.

7) **Open Alkali Wetland**- a wetland which is devoid of all vegetation in it's central vegetation zone, except for *Ruppia maritima*.

8) **Disturbed Wetlands**- areas either cultivated, grazed or drawn down. Vegetation is primarily forbes mixed with low stature grasses.

The Canadian Wetland Classification System (Zoltai *et al.* 1975) developed by the National Wetlands Working Group is broader in it's application and hierarchical, starting with wetland classes that are based on vegetation, hydrology, and water quality. These classes are bog, fen, swamp, marsh, and shallow open water. According to the Wetlands Working Group, bogs are wetlands that have accumulated over 40 cm of peat. The living vegetation is not enriched by groundwater and is hence ombrotrophic. Correspondingly the water is nutrient poor and acidic (pH < 4.6, specific conductivity < 80 µS). Vegetation is dominated by *Sphagnum* mosses, and ericaceous shrubs. *Picea* trees may be present. Fens have high water tables that are situated on gentle slopes. The water source is a mixture of precipitation and groundwater, thus it has a higher nutrient status and pH than bogs. In situations where groundwater sources are extremely nutrient poor, fens can have low pH and nutrient levels, similar to those of bogs. These nutrient poor fens can also be dominated by *Sphagnum* mosses. However, other fens are dominated by brown mosses mostly of the family Amblystegiaceae, with sedges, shrubs, and trees. Swamps are nutrient rich, oxygenated, productive sites, which have luxuriant tree and shrub cover. The water table is high, persisting as standing water for long periods of time, or as subsurface groundwater flow. Peat forming mosses are absent or minimal, and the peat is often highly humified and woody. Wetlands that are periodically inundated, resulting in the addition of nutrient rich waters and mineral soil are marshes. Marsh waters are oxygen rich and circumneutral to slightly alkaline. Vegetation is dominated by reeds, rushes, and sedges. The Wetlands Working Group defines shallow open waters as small non-fluvial bodies of standing water. Emergent vegetation is lacking, but floating and rooted aquatic macrophytes may be present. Midsummer water depth is less than 2 meters. The next level of hierarchical division for this classification system is the wetland form. It is based upon the surface morphology of the wetland, presence of surface patterns, tidal effects, and proximity to water bodies. These forms reflect differences caused by environmental factors.

OBJECTIVES

Elk Island National Park was chosen as a suitable location for the documentation of the effect of early Holocene climate on peatland development because of: a) the regional sensitivity to early Holocene climate that has been documented in the paleolimnological and pollen record, b) its close proximity to the southern limit of coniferous trees and, c) its geographical position in a southern extension of the mixedwood section of the Boreal Forest. It was well known that a diversity of wetland types exist within the park, allowing the study of wetland processes on a variety of wetland types. The objectives of this thesis are:

a) To inventory and classify the wetlands of Elk Island National Park.

b) To inventory surface water chemistry and physical parameters (peat depth, water level fluctuations, and elevation) characterizing wetlands in the park.

c) To outline relationships between vegetation, surface water chemistry, and physical parameters.

d) To examine the influence of the early Holocene thermal maximum on the development of wetlands in the park.

e) To identify the hydroseral successional patterns that have occurred in the wetlands through an evolutionary study of peat macrofossils.

f) To identify some of the processes controlling peatland development in the park, and examine the influence of allogenic and autogenic factors on peatland development.

STUDY AREA

Elk Island National Park is located 37 km east of the eastern limit of the city of Edmonton, in the center of a physiographic region known as the Alberta Plain (Lang 1974). On the Alberta Plain are several hills, known as the Beaver Hills, which rise above the level of the surrounding landscape. About 30 m of overburden, consisting of morainic materials deposited from disintegrating ice sheets separate the surface from the underlying bedrock (Bayrock and Hughes 1962). The sedimentary bedrock in this area is of the Belly River Formation (Emerson 1977), and consists of non-marine sandstones, siltstone, and mudstones. These rocks were formed during the Upper Cretaceous and are erosional products from previously existing hills (Lang 1974). Tills in Elk Island National Park are formed from hummocky stagnant ice moraine (Lang 1974), giving the area a rugged topography characterized by knobs, kettles, till hummocks and till ridges (Scace and Associates Ltd. 1976). Prairie mounds are a distinctive feature of dead-ice moraine and within the Beaver Hills these mounds are circular, with a basal diameter of about 91 m, and a rim that rises 5 m above the surrounding land. Within the central depression, a thin layer of lacustrine deposit can usually be found (Emerson 1977).

There is evidence, in the form of glaciofluvial deposits and landforms, that the Beaver Hills experienced a greater supply of surface water during the ice stagnation than at present (Emerson 1977). At Elk Island, this evidence occurs as small meltwater stream trenches at Tawayik and Oster Lakes. This is a route from which drainage water collected in the southern half of Elk Island National Park flowed northward into glacial Lake Edmonton (Emerson 1977). Glaciolacustrine sediments were also deposited in a hummocky area southwest of Astotin Lake (Crown 1977), and the southeastern part of the Park (Lang 1974).

Climate

The mean annual temperature for Elk Island Park is 1.5°C (Parks Canada 1986), with a mean summer temperature of 9.3°C. The region surrounding the park receives 400-500 mm of precipitation annually, with between 325 and 391 mm as rain. June, July and August are the wettest months. The area experiences on average between 1278 to 1560 growing degree days a year, and 109 to 140 frost free days.

Vegetation

There has been much controversy in the past regarding the concepts and boundary locations of the main phytogeographic regions or forest regions surrounding Elk Island National Park. In 1955, Moss placed Elk Island in the Parkland Prairie phytogeographic region of Alberta (Parks Canada 1986); later Rowe (1972) placed Elk Island in the Boreal mixedwood forest region. In a recent ecological land classification by Strong and [illegible]at (1981), Elk Island was placed in the Boreal mixedwood. Consultants for Parks Canada (Parks Canada 1986) considered the Park to be in the Parkland-Boreal Forest Transition Ecoregion, as it contains areas of aspen groves and mixedwood forest. According to the latest Ecoclimatic regions of Canada publication (Ecoregions Working Group 1989), Elk Island National Park is in the Transitional Grassland Ecoclimatic Region, a transition zone between semi-arid prairie, and moister boreal forests. Vegetation studies done for Parks Canada at Elk Island identified 15 communities comprised of *Populus tremuloides*, *Populus tremuloides-Populus balsamifera*, *Betula papyrifera*, *Picea glauca*, and *Picea mariana*. Three of the fifteen were shrub communities of *Betula*, *Salix* and *Ledum groenlandicum*. Six grass and sedge communities were described: *Puccinellia distans*, *Poa pratensis*, *Bromus inermis*, *Carex*, *Carex-Salix*, and *Typha*. The most common assemblages were found to be the *Populus* assemblage with *Corylus cornuta* and *Aralia nudicaulis* as co-dominants; a shrub assemblage with *Poa pratensis*; the grass assemblage *Poa pratensis*; and the *Carex* and *Typha* assemblages. In terms of land area, the most widespread community types are the *Typha-Carex*; *Carex*; and *Carex-Petasites* dominated vegetation occupying 53% of the park's land area (Parks Canada 1986).

METHODS

Vegetation Inventory

Preliminary airphotographic reconnaissance and information from previous vegetation and soils studies available at Elk Island Park (Crown 1977, Parks Canada 1986) indicated that approximately ten wetland types (including peatlands) could be identified within the park. Based on these surveys, 63 wetlands were chosen for the vegetation inventory. Wetland selection was based on adequate duplication of the ten major wetland types, adequate geographic coverage of the park and reasonable access. Fig. 1 outlines the location of wetland sites inventoried. At each of the 63 wetlands, stands were identified based on uniform vegetation, generally arranged in zones. From one to three relevés each of 10 square meters were randomly placed within each stand. Vegetation was described on a percentage cover basis, and mean cover values of the one to three relevés were calculated for each stand. Voucher specimens were collected for vascular plants and bryophytes and are deposited in the University of Alberta herbarium (ALTA). Authority names and nomenclature for vascular plants follows Moss (1983), except for Cyperaceae (Taylor 1983); the genus *Sphagnum* follows (Vitt and Andrus 1977), the genus *Drepanocladus* (Janssens 1983), other bryophytes (Ireland 1982), hepatics (Schuster 1953), and lichens (Hale 1979). Physical parameters measured at each relevé included: water depth measured in open pools or shallow pits, hummock height, and pH of surface waters. Site elevation was taken from Canada Dept. of Energy, Mines and Resources (1987) 1:50,000

ELK ISLAND NATIONAL PARK

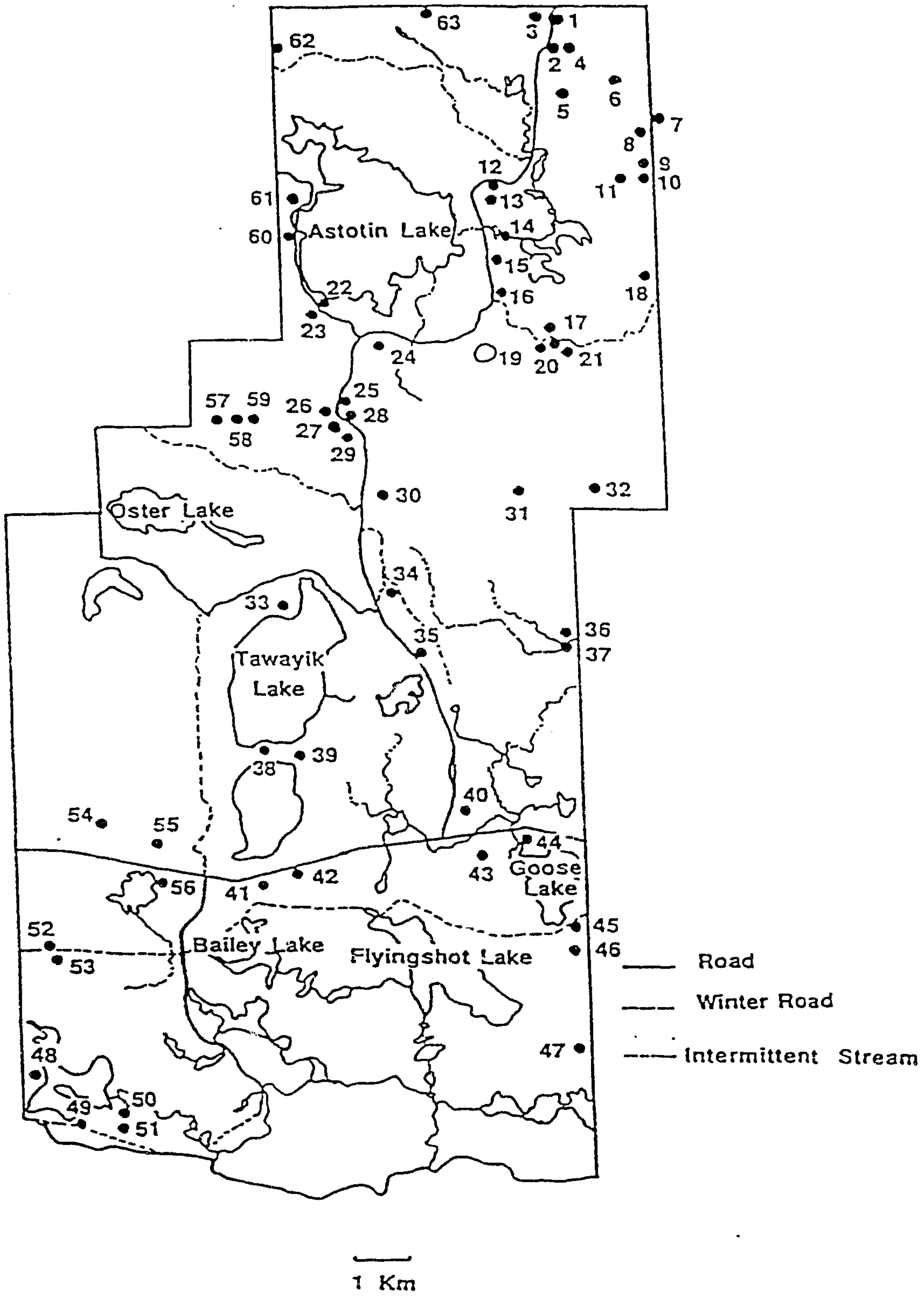


Figure 1. Location of 63 Wetlands Used In The Vegetation Stand Inventory

contour maps, and the number of streams entering and exiting from 1:30,000 aerial photographs of the Park.

Water Chemistry

On May 15-16 and September 18-20, 1989, water samples were collected from open pools or shallow pits from the stands. Samples analyzed for specific conductivity and cations were stored in acid washed 60 ml polyethylene and polypropylene bottles. Samples analyzed for total phosphorus were stored in 500 ml polypropylene bottles, while samples analyzed for total Kjeldahl nitrogen, nitrate, and ammonium were placed in 60 ml and 500 ml polystyrene bottles. All nutrient (TKN, nitrate, ammonium, total phosphorus) samples were analyzed within 24-48 hours; cation samples were preserved with 1 ml of 1.5 N HCL and analyzed at a later date. All pH measurements were taken in the field using a portable Beckman 10 pH meter. Specific conductivity measurements were done in the lab with a Radiometer conductivity meter. Results for specific conductivity were adjusted to 25^{0}C and corrected for hydrogen ion activity (Sjörs 1952). Cations were analyzed at Forestry Canada, Northern Forestry Center, Edmonton, Alberta, on an inductively coupled plasma spectrophotometer. Nitrate and ammonium were analyzed at the University of Alberta, Department of Zoology, on a Technicon autoanalyzer, and total Kjeldahl nitrogen samples were persulfate digested using methods outlined by D'Elia *et al.* (1976).

Stand data were analyzed by TWINSPAN, a Fortran program that orders multivariate data into a classification scheme (Hill 1979). Spearman's Rank Correlation statistic, a non-parametric statistic, was used to obtain correlations between the Twinspan classification, water chemistry, and physical parameters.

Wetland Development Analysis

Classification of the vegetation data by TWINSPAN identified in thirteen vegetation groups. Based on this analysis, six representative peatlands were subjectively selected from the 63 sites for a development analysis (Fig. 2). In order to analyze developmental trends, sites were selected representing the seral stages of bog, fen and marsh. A bog which had been disturbed by beaver activity was added after the first field season in response to a request from the staff at EINP. Cores were removed at each site in a transect. Depth to mineral substrate was determined by probing with iron rods at 30.5 m. intervals to develop basin configuration at five sites. Triplicate peat cores were removed manually with a modified 5 cm diameter Macaulay peat corer. One core was used for macrofossil analysis, the second for peat chemistry and the third for radiocarbon dating. Macrofossil analysis follows the methodology of Janssens (1988), in which subsamples of a known volume are removed from the core, soaked for three days in Aerosol O.T. Solution (a non-foaming wetting agent), and wet sieved with a 150 µm soil sieve. Relative percentages of the macrofossils present in the subsample were determined using a dissecting microscope. Seeds, bracts, and reproductive structures too small for percentage estimates were counted directly. Zonation of the peat profile into peat phases was determined visually based on species composition and ecology. The central core from each transect has been illustrated in detail with all

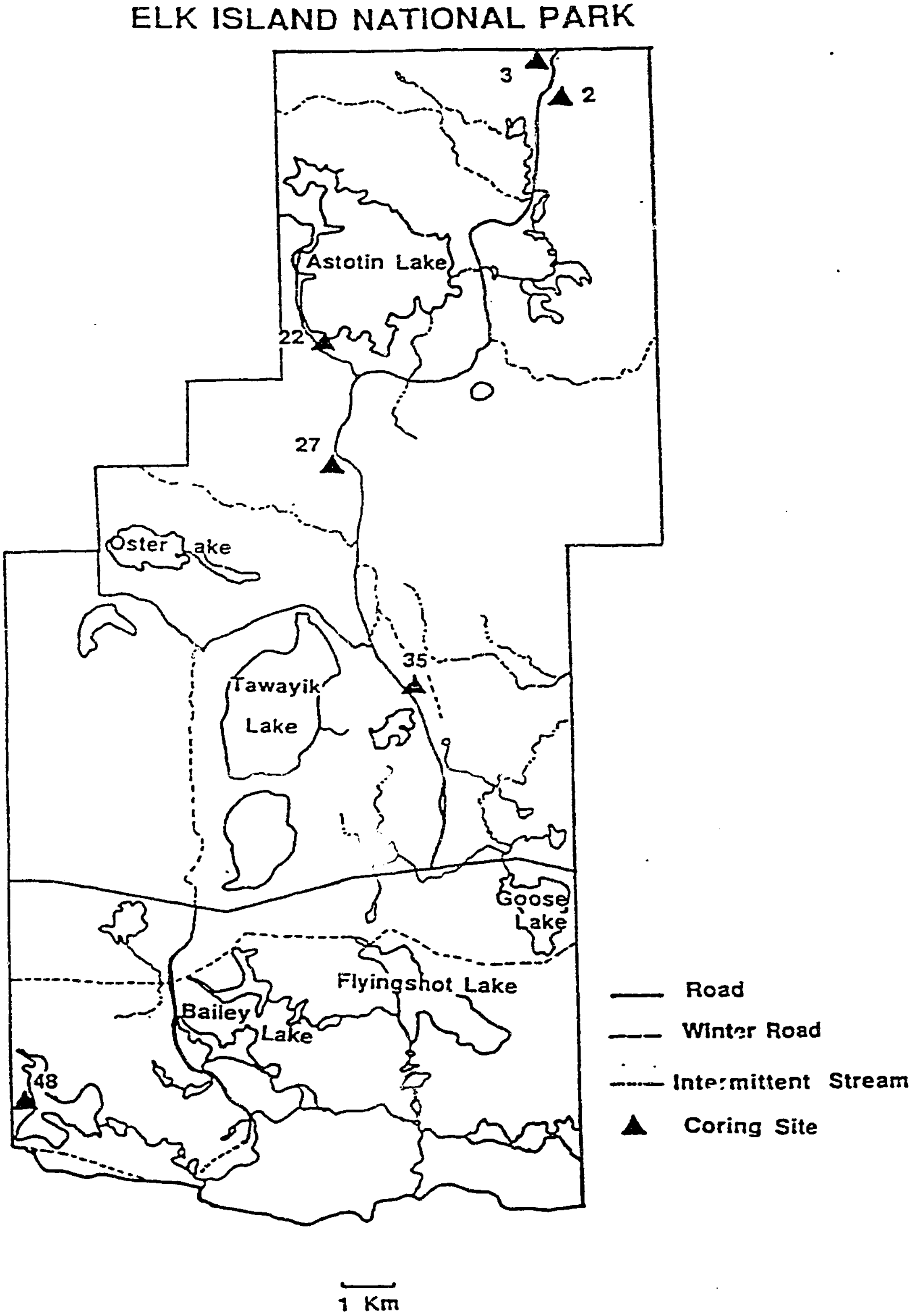


Fig. 2. Location of Six Peatlands Used For Evolutionary Analysis

macrofossil fragments and seeds identified. For the remainder of the cores from each transect, summary diagrams are presented outlining the important macrofossils. A detailed listing of all macrofossil fragments and seeds identified in the summary diagrams is presented in Appendix I. Paleoenvironmental reconstructions of height above water table and pH were calculated based on the known modern autecology of specific moss species. Weighted species means of height above the water table and local pH were calculated on 1331 reléves measured throughout western Canada (Gignac *et al.* 1991a,b).

$$\mu k = \Sigma_{i=1}^{n} Y_{ik} X_i / Y_{+k}$$

Where Y_{ik} is the abundance measured as % cover of species k on reléve i, X_i is the pH or height above the water table for reléve i, and Y_{+k} is the total abundance of species k.

Hydrogen ion measurements were log transformed to approach a normal distribution before calculating weighted means, then backtransformed to the original scale. This method is more accurate than using untransformed data because the resulting means account for the skewness in the data (Gignac pers. com.). Weighted means for pH and height above the water table for mosses in the modern reference data set are presented in Appendix II. Inferred pH and height above the water table (x) for macrofossil sample (m) was calculated as follows:

$$X_m = \Sigma_{k=1}^{p} Y_{km}\, \mu K / Y_{+m}$$

where Y_{km} is the abundance of moss species k in macrofossil sample m, μk is the modern weighted mean of moss species k, and Y_{+m} is the total abundance of mosses in macrofossil sample m.

Peat Chemistry

Peat chemistry samples were removed from each core at 10 cm intervals and major macrofossil boundaries as seen in the field. Each sample was weighed, oven dried at 105°C for 1-2 days and reweighed to derive bulk density measurements. Samples were then ground with a mortar and pestle. Subsamples of 0.2-0.3 g were removed, dry ashed at 470°C, and acid digested with of 6 ml of 1.5 N HCL and 1 ml of concentrated HNO_3. Digested solutions were then filtered through Whatman #42 filter paper and analyzed by inductively coupled plasma spectrophotometry. Results are given in mg/Kg of peat. Radiocarbon dates were obtained at the Radiocarbon and Tritium Laboratory in Vegreville, Alberta. After the macrofossil analysis were completed the peat samples were assigned to one of eight peat type categories based on the results. In order to asses how the peat types based on macrofossil composition differed chemically a SAS/STAT canonical correlation and discriminant analysis were performed. The discriminant analysis creates composites of the chemical variables showing maximum differences among the peat types. The canonical correlation defines the relationships between the chemical variables (Thorndike 1978). Group means were plotted in discriminant space to graphically show the relationships between the peat types. Multivariate statistics test the hypothesis that the class means are equal in the population.

RESULTS

Vegetation Classification

274 relevés from the 63 wetlands contained 260 species (Table 1) from 156 stands. TWINSPAN analysis classified these stands into 13 ecologically meaningful stand groups.

Group 1 consists of one unique stand located at site 49 a brackish environment. Dominant species are *Triglochin palustris*, *Triglochin maritima*, and *Eleocharis palustris*. Species present in minor abundance are *Ranunculus gmelinii*, *Scirpus validus*, and *Rumex britannica*. Species diversity is low in this stand with 2.3% of the total species present.

Group 2 is a small group of 10 stands located predominantly along lake edges. Characteristic species are *Typha latifolia*, *Lemna minor*, *Carex atherodes*, *C. aquatilis*, *Sium suave*, and *Ranunculus gmelinii*. Bryophytes are absent except for minor occurrences of *Drepanocladus polycarpus*. Species diversity is low with only 20% of the total species present.

Group 3 contains 22 stands, characterized by high *Lemna* and *Carex* cover, and can be found at wetland margins, on shallow peats, and in areas recently flooded by beaver (*Castor fiber*). The *Carex*

Table 1
Twinspan Vegetation Groups
Wetlands of Elk Island National Park

Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Species													
Bidens cernua		+	+		+	+	+				0.67		
Lemna trisulcata		0.8	+		+						0.67		
Utricularia vulgaris		0.6	+		+			+					
Glyceria pulchella			+	+		+						+	
Riccia fluitans		+	+		+						+		
Eleocharis palustris	4	1.2	+			+	+				+		
Lemna minor		1.3	2	+	+	+	+				0.67		
Polygonum amphibium		+	0.86		+	+	+						
Ranunculus gmelinii	1	1	+		+	+	0.56				+		
Scirpus validus	1	+	+			+							
Trigochin palustris	3			+		+							
Typha latifolia		3.4	0.73	+	+	+					+		
Carex atherodes		1.3	2.18			1.03	+		+				
Carex bebbii		+	+		+	+							
Beckmannia syzigachne		+	+			+							
Glyceria grandis			0.91		+	+							
Hordeum jubatum			+			+							
Hippuris vulgaris		+	+	+	+								
Utricularia minor		0.6	+	+	+								
Carex rostrata			1.45	0.58	1.73	0.69	0.56				+		
Cicuta bulbifera		+	+	+	+	+						+	
Galium trifidum		1	0.91	+	0.93	1.28	0.56		+			+	
Sium suave		1.2	0.82	+	+	0.52	+				+		
Calamagrostis stricta		+	+	0.58	+	0.66							
Epilobium leptophyllum		+		+	+		+			+			
Mentha arvensis		+	+	+	+	0.79	0.67	+			0.67		
Stellaria longifolia		+	+	+	+	0.97	0.78	+	+		0.67		
Carex aquatilis		1.7	2.55	1.54	3.57	1.86	+	+	+	1.5	1		
Cirsium arvense			+			+							
Epilobium ciliatum		+	+	+	+	+	0.56					+	
Stachys palustris			+	+		0.59	+						
Urtica dioica		+	+		+	+	+						
Scholochloa festucaea		+	+		+	+							
Salix petiolaris		+	+	+	+	0.55							
Cicuta virosa		+	+	+	+	+	+						
Geum aleppicium			+	+	+	+							
Rumex britannica	1	+	+	+	0.87	0.93	+		+				+
Scutellaria galericulata		+	+	+	+	1.21	0.67		+		+	+	
Salix serissima			+	+	+	0.83			+	1	0.67	+	+
Aster borealis			+	+	+							+	
Impatiens capensis		+	+		+	+	2					1.33	
Lycopus uniflorus		+	+		+	0.66	0.56	+			0.67		
Agrostis scabra			+	+	+	0.93	+	+	+				+
Poa palustris		+	+		+	0.66		+					
Salix bebbiana				+	+	+	+		+				
Salix discolor		+	+	+	+	1.24	+		+	1	+		
Salix exiqua					+	+							+
Aster puniceus			+	+	+	1.1	0.67				+	1	
Caltha palustris			+	+	+	0.59	1.44					0.67	
Geum rivale		+	+		+	0.62	0.89					1	
Lonicera involucrata				+	0.67	+	0.89				+	0.67	
Petasites sagittatus			+	0.54	+	1.07	0.56					0.67	+
Ribes glandulosum						+	+					+	
Ribes lacustre			+			+	0.56				+		
Bromus ciliatus				+		0.52	+	+					+
Amblystegium serpens				+	+	+	+						
Climacium dendroides		+	+	+	+	1	1		+		0.67	+	
Hypnum pratense				+	+	+	+				+	0.67	
Marchantia polymorpha				+		+	1.33					0.67	
Plagiomnium ellipticum			+	0.92	0.67	0.97	2.11				+	1.67	
Potentilla palustris		+	+	1.83	1.67	1.38	1.56		+	1	+	+	0.6
Plagiomnium medium					+	+	+						
Equisetum fluviatile				1.08	0.67	+	2.33			1		1.67	
Eriophorum polystachion				0.88	+		+						
Lysimachia thyrsiflora			+	+	+	0.66	0.78		+		0.67	0.67	
Menyanthes trifoliata				1.79	+	+	+			1.5	+	1.33	
Brachythecium mildeanum			+	1.46	+	0.76	0.78	+	+			1.33	0.6
Calliergonella cuspidata				+			+					0.67	
Drepanocladus aduncus			+	0.67	0.67	+		+				+	
Drepanocladus polycarpus		0.6	+	1.33	1.23	1.07	+	+	+		+	0.67	+
Cornus stolonifera					+	+	+					+	

Table 1 continued

Group Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Ribes oxyacanthoides				+	+	+	+						
Viola palustris					+	+							+
Salix pedicellaris				1.38	+	+		+	+			+	
Drepanocladus capillifolius				+	+	+						+	
Salix candida				+	+	+	[illegible].56						
Equisetum arvense				+	+	+							
Triglochin maritima	3			0.71	+	+							
Carex chordorrhiza				+		+							
Carex diandra		+		1.79	+	+	+	+				+	
Carex canescens				+	+	+							
Carex lasiocarpa				2.38	0.77	+		+		1			
Drepanocladus vernicosus				1.5	+			+					1.6
Calamagrostis canadensis		+	0.91	1.25	1.1	2.9	2.22	0.87	1		3	1	
Calla palustris				+	+	+				1			
Tomenthypnum nitens				0.75	+	+	+		+			0.67	
Salix pyrifolia		+	+	+	0.67	+	+	+	+		0.67		+
Rubus acaulis				0.83	+	1.31	1.44	+			1	2	0.6
Drepanocladus exannulatus				+		+					+		
Sphagnum squarrosum				+	+	+		+	+	+	+		
Dryopteris carthusiana					+	+	+		+			+	
Mitella nuda						+	+					0.67	
Ribes hudsonianum					+	+	1.33		+		+	+	
Rubus idaeus					+	+	+	+	+		+	0.67	+
Viola renifolia				+	+	+	+				1	+	
Viola spp.					+	+						0.67	
Pyrola secunda			+	+		+						+	
Rhizomnium gracile			+					+	+				
Alnus tenuifolia			+	+	+	+	+	+	+		0.67	+	+
Galium boreale		+				+	+					1.33	
Pyrola asarifolia			+	+		+	+					1.33	
Salix spp			+	+	+		+	+	+				+
Bryum pseudotriquetrum			+	0.79	+	+	+	+	+				+
Calliergon stramineum				+	+						0.67		
Epilobium angustifolium					+	+	+	+	+		0.67		+
Aulacomnium palustre				1.33	+	+	+	1.2	0.83	+	1.67	1.33	1.6
Calliergon giganteum				0.88	+	+	1.22	+			2.33	1.33	
Helodium blandowii				+	+	+		+			0.67	+	
Betula pumila				1.21	+	+		0.8			1.33	+	1.6
Lophocolea heterophylla				+	+	+		+	+				+
Larix laricina				0.79	+	+	+	+		2		1	+
Carex limosa				+						2			
Betula neoalaskana				0.58	+	+	1.56	1.13			2.33	1	1.4
Plagiothecium denticulatum			+	+	+	+	+	+	+			1	
Cornus canadensis					+	+	+	+	+			1.67	
Pohlia nutans			+	+	+	+	+	+	+			1.67	0.6
Picea glauca				+		+	+	0.53				3.33	
Carex disperma				+	+	+	1	+	0.83		0.67	2	1
Cinna latifolia			+	+	+		+					1.67	
Brachythecium campestre						+	+		+			1	
Betula glandulosa					+	+	+	+		2.5			0.8
Carex curta		+		0.58	+	+		0.67	0.67	1	0.67		0.8
Carex paupercula				+	+	+	+	+		1	0.67		+
Sphagnum teres				+	+	+	+	0.67		4	1.67		1.2
Eriophorum vaginatum				0.67	+	+		1.93	+	2	1		1.2
Sphagnum warnstorfii				+	+	+	+	0.93	1.17	1.5	2	2	2.4
Ledum groenlandicum		+		+	+	+	+	3.4	2.83	1	2.67	2	3.2
Oxycoccus microcarpus				+		+		1.6	1.67	2.5	1	0.67	1.6
Rubus chamaemorus						+		2.67	2.33		2	0.67	3
Smilacina trifolia				+	+	+	+	0.93	1.17	1	2	1	1.2
Vaccinium myrtilloides								1.67	0.83		1	0.67	2
Polytrichum strictum					+	+	+	1.93	0.83	2	0.67	1	1.8
Sphagnum angustifolium				+	+	+	+	2.07	1	2.5	1.67	1	2.2
Sphagnum mangellanicum					+	+	+	2.33	1		1.67	1	2.4
Sphagnum russowii					+			1.27			0.67	+	+
Picea mariana				+	+	+	+	1.47	3		+	1	1
Vaccinium vitis-idaea						+	1.11	2	2.33			1.67	1.8
Dicranum undulatum				+	+		+	+	+			+	+
Lophozia spp.						+		+	0.83				+
Polytrichum juniperinum							+	+	1.17				2
Sphagnum fuscum					+			1.6	1.17		+		0.8
Sphagnum nemoreum				+	+			0.87	2.5				
Cladina mitis						+	+	+	1		+	+	+
Cladina rangiferina								+	0.67				+
Cladonia chlorophaea							+	+	0.83				
Betula papyrifera			+	+		+	+	0.8	1.17				0.6

Table 1 continued

Group	1	2	3	4	5	6	7	8	9	10	11	12	13
Species													
Hylocomium splendens						+	+		0.83			1	
Pleurozium schreberi						+	+	0.67	2			2.33	0.6
Ptilidium crista-castrensis						+	+	+	+			1	+
Sphagnum centrale							+	+	+			1.33	+
Species with minor occurrences													
Juncus bufonius			+										
Monolepis nuttalliana			+										
Ranunculus lapponicus		+	+										
Rorippa palustris		+	+			+							
Sparganium angustifolium		+											
Viola canadensis			+										
Phalaris arundinacea		+				+							
Myriophyllum exalbescens		+											
Potamogeton pectinatus			+										
Drepanocladus lapponicus			+										
Funaria hygrometrica			+										
Lysimachia thrysiflora		+											
Riccocarpus natans		+	+		+								
Rhizomnium ellipticum			+		+								
Achillea millefolium		+				+							
Equisteum pratense				+		+							
Ribes americanus			+			+							
Senecio eremophilus		+	+			+	+						
Carex lacustris			+		+	+							
Salix maccalliana						+							
Salix scouleriana						+							
Amelanchier alnifolia						+							
Achillea sibrica						+							
Anemone canadensis						+							
Amenone cylindrica						+							
Cardamine pensylvanica						+	+						
Equisetum palustre						+							
Fragaria vesca			+			+							
Erysimum sp.						+							
Galium triflorum						+	+						
Geum macrophyllum				+		+							
Lathyrus ochroleucus						+							
Lathyrus venosus						+							
Potentilla norvegica						+							
Potentilla paradoxa			+			+							
Ribes triste							+						
Ribes viscosissimum						+							
Solidago canadensis						+							
Solidago gigantea							+						
Viola nephrophylla						+							
Carex sychnocephala						+							
Elymus glaucus						+							
Carex brunnescens						+							
Brachythecium plumosum							+						
Cephalozia connivens						+							
Leptobryum pyriforme						+							
Plagiomnium cuspidatum						+							
Peltigera canina						+	+						
Rhizomnium pseudopunctatum				+		+							
Salix pseudomonticola				+	+	+	+						
Parnassia palustris				+	+	+							
Ranunculus macounii				+		+							
Rosa acicularis				+	+	+							
Senecio indecorus					+	+							
Spiranthes romanzoffiana				+		+							
Carex retrorsa				+		+	+						
Thuidium recognitum				+		+							
Salix arbusculoides				+									
Salix candida				+	+	+	+						
Moneses uniflora				+									
Scheuchzeria palustris				+									
Carex tenuiflora				+									
Campylium polygamum				+									
Cephalozia bicuspidata				+									
Drepanocladus revolvens				+									
Meesia triquetra				+									
Peltigera aphthosa				+									
Sphagnum contortum				+									
Calamagrostis inexpansa	+			+	+	+				+			
Petasites palmatus				+	+	+						+	

Table 1 continued

Group Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Carex trisperma					+	+							+
Hypnum lindbergii				+		+			+				
Equisetum sylvaticum						+							+
Campylium radicale						+						+	
Habenaria hyperborea				+		+						+	
Pinus banksiana				+	+			+					
Lycopodium annotinum						+							+
Cladonia scabriuscula					+		+					+	
Ceratodon purpureus						+			+				
Salix planifolia					+	+							
Drepanocladus uncinatus						+	+		+				+
Populus tremuloides				+		+			+				
Cladonia cucullata				+				+					
Andromeda polifolia				+						+			+
Drosera rotundifolia					+					+			+
Kalmia polifolia											+		
Cephalozia lunulifolia							+				+		+
Calypogeia sphagnicola							+	+			+		+
Scirpus hudsonianus									+				
Trifolium repens								+					
Mylia anomala								+	+				
Ptilium pulcherrimum								+					
Sphagnum fallax								+					
Sphagnum riparium								+					
Sphagnum subsecundum				+					+				+
Cladonia cornuta						+		+	+				
Cladonia deformis									+				
Cladonia furcata								+	+				
Cladonia gracilis									+				
Cladonia verticillata								+	+				
Cetraria nivalis						+		+	+				+
Cetraria cucullata									+				
Dicranum polysetum												+	
Lepidozia reptans												+	
Tetraphis pellucida									+			+	
Cladonia coniocraea												+	

Numbers are mean abundance values of each TWINSPAN vegetation group on a scale from 1-4, cut levels were 0, 2, 20, 50
+ = a mean abundance TWINSPAN value of < or = 0.5

species are broad-leaved and consist of *Carex aquatilis, Carex rostrata,* and *Carex atherodes.* Other species that occur are the grasses *Beckmannia syzigachne, Hordeum jubatum, Glyceria grandis,* and *Calamagrostis canadensis,* and other angiosperms *Polygonum amphibium, Typha latifolia, Galium trifidum, and Sium suave.* Bryophytes are not major components of this group and consist of only a few occurrences of *Plagiomnium ellipticum, Brachythecium mildeanum, Drepanocladus polycarpus,* and *D. aduncus.* Thirty-two percent of the total species are found in these stands.

Group 4 contains 24 stands that can either be found in floating mats at lake edges, as slightly raised center mats, or at the edges of peatlands. This stand group contains a mixture of the narrow-leaved carices, (*Carex lasiocarpa, C. diandra*), and broad-leaved carices, (*Carex aquatilis, Carex rostrata*). *Larix laricina* and *Salix pedicellaris,* as well as the grasses *Calamagrostis canadensis* and *C. stricta,* can be present. Other common vascular plants include *Menyanthes trifolitata, Potentilla palustris, Betula pumila, Betula neoalaskana, Equisetum fluviatile, Eriophorum polystachion* and *Eriophorum vaginatum.* Bryophytes form important components of these stands, particularly *Brachythecium mildeanum, Plagiomnium ellipticum, Drepanocladus polycarpus, D. vernicosus, Tomenthypnum nitens, Calliergon giganteum,* and *Calliergonella cuspidata.* Forty-seven percent of the total species are present in these stands.

Group 5 contains the largest number of stands (30), and was sampled under a variety of conditions. The stands are characterized by high cover of *Carex aquatilis,* and *C. rostrata,* two common broad-leaved species. Bryophytes are less important than in group 4.

Common secondary species are *Calamagrostis canadensis, Carex lasiocarpa, Galium trifidum, Rumex britannica, Petasites sagittatus, Potentilla palustris, Drepanocladus polycarpus, Drepanocladus aduncus*, and *Plagiomnium ellipticum*. Species diversity is relatively high, with 49% of the total species present.

Group 6 contains 29 stands that are generally located on either shallow peat or on the edges of peatlands. These stands are dominated by *Salix* trees and shrubs with high grass cover in the understory layer. *Salix discolor* is the most common *Salix* species, followed by *S. serissima*, and *S. pyrifolia*. Grasses are dominated by *Calamagrostis canadensis* and *Agrostis scabra*, while *Carex aquatilis* and *C. atherodes* are the most common carices. Flowering plants are diverse and include *Potentilla palustris, Cicuta bulbifera, Scutellaria galericulata, Petasites sagittatus, Stellaria longifolia, Rumex britannica, Galium trifidum, Aster puniceus*, and *Rubus acaulis. Drepanocladus polycarpus* is the only bryophyte of importance in this group. Species diversity is the highest in this stand group with 71% of the total species present.

Group 7 is a second series of stands that appears commonly along the edges of the wetlands. This group of 10 stands has the highest percentages of *Alnus tenuifolia, Salix candida*, and *Betula neoalaskana*. *Picea mariana, P. glauca, and Larix laricina* are also found, but with low cover. The grass, *Calamagrostis canadensis*, is also an important component. Other vascular plants that are prevalent include: *Equisetum fluviatile, Potentilla palustris, Impatiens capensis, Vaccinium vitis-idaea, Ribes hudsonianum, Rubus acaulis*, and *Aster puniceus*. Bryophytes are common in this vegetation, particularly *Brachythecium mildeanum, Calliergon giganteum, Aulacomnium palustre, Sphagnum warnstorfii, Pleurozium schreberi, Plagiomnium ellipticum, Climacium dendroides,* and *Marchantia polymorpha.* Thirty-eight percent of the total species are present in this group.

Group 8 contains 10 stands found in the more open peatlands. Vegetation is dominated by *Sphagnum* mosses and ericaceous shrubs. The *Sphagnum* species include: *S. fuscum, S. magellanicum, S. angustifolium, S. russowii,* and smaller amounts of *S. warnstorfii,* and *S. nemoreum.* Ericaceous shrubs consist of *Ledum groenlandicum, Oxycoccus microcarpus, Vaccinium myrtilloides,* and *V. vitis-idaea.* Vascular plant species are limited and dominated by *Rubus chamaemorus* and *Eriophorum vaginatum.* Lichens, particularly *Cladina mitis, C. rangeriferina, and C. chlorophaea* are present. Species present in this group are 26% of the total.

Group 9 also consists of 6 stands found in *Sphagnum*-dominated peatlands, but with a heavy black spruce (*Picea mariana*) cover (Table 1). Ericaceous shrubs are significant in Group 9 as well as the *Sphagnum* species *S. fuscum, S. magellanicum, S. angustifolium, S. nemoreum,* and *S. warnstorfii.* Feather mosses and lichens have high abundance, particularly *Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis, Cladina mitis, C. rangiferina,* and *C. chlorophaea.* Thirty percent of the total species are found in this group.

Group 10 consists of two *Sphagnum*-dominated stands that have high *Larix laricina* cover. These stands are restricted to site 7. In addition to *Larix, Salix discolor, S. serrissima,* and *Betula glandulosa* are prevalent. Other important vascular plants are *Oxycoccus microcarpus, Smilacina trifolia, Eriophorum vaginatum, Carex aquatilis, C. paupercula, C. limosa, C. curta,* and *Menyanthes trifoliata. Sphagnum teres, S. warnstorfii, and S. angustifolium* are the important *Sphagnum* in this group. Species diversity is low at 11%.

Group 11 is a group of three *Sphagnum*-dominated stands that occur predominantly on the edge, and are most similar to stands of Group 13. Group 11 contains, in addition to *Sphagnum*, species that are normally restricted to much more minerotrophic conditions. These species are *Alnus tenuifolia, Betula pumila, Betula neoalaskana, Carex aquatilis, Calamagrostis canadensis, Bidens cernua, Lemna minor, L. trisculata, Lycopus uniflorus, Viola renifolia, Epilobium angustifolium, Mentha arvensis, Stellaria longifolia, Aster puniceus, Lysmachia thrysifolia,* and *Menyanthes trifoliata.* These stands also contain bryophytes that are indicative of minerotrophic conditions. These are *Climacium dendroides, Hypnum pratense, Drepanocladus exannulatus, D. polycarpus, Calliergon stramineum,* and *C. giganteum,*

Group 12 is comprised of dense *Picea glauca, P. mariana, and Larix laricina* stands that contain an ericad understory, *Sphagnum,* and feather mosses. Ericaceous shrubs consist of *Ledum groenlandicum,* and *Vaccinium vitis-idaea. Sphagnum* species of importance are *S. warnstorfii, S. centrale, S. angustifolium, S. magellanicum,* and *S. russowii.* Several species of bryophytes and vascular plants occur here that are less frequently associated with *Sphagnum.* These are the bryophytes *Plagiomnium ellipticum, Plagiothecium denticulatum, Pohlia nutans, Brachythecium mildeanum,* and *B. campestre*; and the vascular plants *Geum rivale,* *Galium boreale*, *Equisetum fluviatile*, *Cornus canadensis*, *Cinna latifolia*, and *Impatiens capensis*. Thirty-two percent of the total species are present in this group.

Group 13 is a group of 5 *Sphagnum*-dominated stands that have a high cover of *Betula pumila*, *B. neoalaskana*, and *Picea mariana*, mixed with some *Larix laricina*, *Betula glandulosa*, *Salix pyrifolia*, and *Betula papyrifera*. Ericaceous shrubs are important components of this group, as well as *Eriophorum vaginatum* and *Rubus chamaemorus*. Minerotrophic indicators are present, including *Drepanocladus vernicosus*, *Aulacomnium palustre*, *Carex curta*, and *C. disperma*. Twenty-eight percent of the total species are present in this group.

Correlation of Vegetation to Water Chemistry and Environmental Factors

The stand classification produced by TWINSPAN is significantly correlated with 8 water chemistry and 4 physical factors (Table 2). Relationships are present between water level, pH, specific conductivity, calcium, magnesium, sodium, total phosphorus, ammonium, and total organic nitrogen. Stands are also correlated with mean water level at the site, elevation of the site, number of streams entering and exiting the wetland, and hummock height within the stand. The strongest correlations are between vegetation and water chemistry (pH, corrected specific conductivity, calcium, magnesium, sodium), as well as mean water level and hummock height. Slightly lower correlations are obtained relating vegetation

Table 2

Relationship of Wetland Type to Water Chemistry and Environmental Factors

	Saline	Deep	Shallow	Shallow				Mod. Rich	Poor	Poor	Poor			Corr.
Wetland Type	**Marsh**	**Marsh**	**Marsh**	**Marsh**	**Swamp**	**Swamp**	**Swamp**	**Fen**	**Fen**	**Fen**	**Fen**	**Bog**	**Bog**	**Prob.**
Stand Groups	1	2	3	5	6	7	12	4	13	10	11	9	8	
pH	5.2	6.4	6.4	6.1	6.2	5.6	5.9	6.2	4.5	4	4.4	3.5	3.6	.0001
Corr. Spec. Cond. µS	899	534	478	158	326	320	233	162	62	59	42	27	16	.0001
Calcium mg/l	45	65	41	27	26	43	41	33	7	2	6	7	4	.0001
Magnesium mg/l	7	18	10	9	9	12	14	10	3	1	2	2	1	.0001
Sodium mg/l	790	125	31	3	14	22	5	5	3	4	2	2	3	.0001
Organic N µg/l	6384	2166	2527	2013	2977	2628	2013	1577	2645	1362	2843	2918	2979	.0134
Nitrate µg/l	64	175	14	9	10	8	7	8	23	14	16	20	13	.3353
Ammonium µg/l	250	82	133	73	28	62	146	23	82	23	36	162	251	.0346
Total Phosphorus µg/l	1110	252	520	248	650	609	221	135	411	195	374	352	482	.0484
Mean Water Level (cm)	0	21	17	17	7	6	4	10	1	4	6	-9	-15	.0001
Hummock Height (cm)	22	9	12	15	16	16	20	12	24	15	14	31	26	.0001
Elevation (Ft.)	2400	2370	2364	2388	2368	2391	2383	2377	2380	2375	2400	2400	2378	.0220
# Streams	3	2.7	2.5	2.2	2.3	2.4	0.7	2.2	2	3	1.7	2	1	.0048
Peat Depth (M)	1.5	1.4	1.1	2.2	1.2	1.3	2.3	3.7	2.4	2.4	1.7	2.5	2.7	.4399
Number of stands	1	10	22	30	29	10	3	24	5	2	3	6	10	

Corr. Prob. = Spearman Rank Correlation Probability

Corr. Spec. Cond. = Corrected Specific Conductivity stands to nitrogen and phosphorus levels within the wetland, elevation, and the number of inlet and outlet streams.

Integration of the thirteen TWINSPAN vegetation stands into the wetland classification based on the National Wetlands Working Group (1988) results in seven wetland types: saline marsh, deep marsh, shallow marsh, swamp, moderate-rich fen, poor fen and bog (Table 2). The placement of each stand group into a wetland type is based on vegetation definitions of the wetland types and vegetational similarities amongst the stand groups.

The pH is slightly acidic to circumneutral across marsh, swamp, and moderate-rich fen wetland types (Table 2), whereas it declines to about 4.5 in poor fen and 3.5 in bog groups. Similarly, corrected specific conductivity is highest in marsh wetlands (158-899 µS), intermediate in swamp wetlands (233-326 µS), and declines significantly in the moderate-rich fen (162 µS), and poor fens (42-62 µS). Corrected specific conductivity is lowest in the bog wetlands at 16-27 µS. This gradient is repeated for calcium, magnesium, and sodium surface water cation concentrations. Marshes have 27-65 mg/l Ca, 7-18 mg/l Mg, 3-790 mg/l Na; swamps have 26-43 mg/l Ca, 9-14 mg/l Mg, 5-22, g/l Na; moderate-rich fens have 33 mg/l Ca, 10 mg/l Mg, 5 mg/l Na; poor fens have 2-7 mg/l Ca, 1-3 mg/l Mg, 2-4 mg/l Na; and bogs have 4-7 mg/l Ca, 1-2 mg/l Mg, 2-3 mg/l Na.

Nutrient concentrations are not as strongly correlated to stand groups as are cation concentrations and do not follow the ionic gradient outlined in Table 2. Organic nitrogen is highest in the saline marsh at 6384 µg/l. Most of the other wetland types have between 2013-2979 µg/l of organic N. Two fen groups, moderate-rich fen

Group 4 and poor fen Group 10, have comparatively low organic N at 1577 and 1362 µg/l.

Surface water nitrate concentrations are highest in deep marsh wetlands (Stand Group 2) at 175 µg/l, followed by saline marshes (64 µg/l). The remaining stand groups contain between 6.6-19.9 µg/l NO_3.

Ammonium concentrations are highest in the saline marsh and bog Group 8 at 250 µg/l. Intermediate values of 133-162 µg/l were recorded in shallow marsh Group 3, swamp Group 12, and bog Group 9. Lowest values (23-36 µg/l) were found in swamp Group 6, moderate-rich fen Group 4, poor fen Group 10, and poor fen Group 11.

Total phosphorus is highest in saline marsh at 1110 µg/l. Other relatively high values are recorded in swamp Groups 6 (650 µg/l), and 7 (609 µg/l). Lowest total phosphorus concentrations are found in the moderate-rich fen Group 4 (135 µg/l), and poor fen Group 10 (195 µg/l).

Mean water levels are below the surface vegetation only in the bog wetland types as indicated by negative water levels, and at the surface in the saline marshes. Fens and swamps have relatively shallow water table depths, 1.3-9.5 cm and 3.5-7.2 cm respectively. Shallow marsh vegetation is on average covered by 17 cm of water, while the deep marshes were covered by 21 cm of water. Hummock height tends to be lowest in marsh wetlands (9-22 cm), intermediate in fens and swamps (12-23 cm), and highest in bogs (26-31 cm). A positive correlation with site elevation shows a tendancy for marshes to be located at lower elevations, swamps and fens at intermediate elevations, and bogs at the highest elevations. Similarly, bogs (and one of the swamps) have the fewest number of streams entering and exiting the wetlands, while fens, other swamps and marshes have more.

Evolutionary Development

All radiocarbon dates are given in Table 3. The oldest basal radiocarbon date is 6720 +/- 120 yBP. There is no relationship to the amount of peat material accumulated and the age of the deposit nor to the age of the deposit and the type of wetland. Within a given site however, successively younger dates appear towards the peatland edges, in shallower peats. At each site, accumulation rates are highest in the central part of the peatland. Highest accumulation rates occur in the moderate-rich fen sites, followed by the bog sites 27 and 22. Lowest accumulation rates occur in shallow marsh site 35.

Site 2, Core 2-1

The basal radiocarbon date for this peat profile is 5620 +/- 130 yBP at 420 cm (Fig. 3). Basal sediments contain seeds of many aquatic plants such as *Typha* sp., *Scirpus* sp., and *Zannichella palustris*. Oospores of *Chara* sp., the ephippia of cladocera, and the shells of various ostracods and gastropods are also found. Farther up the peat profile (350 cm) bryophytes become prevalent. Leaves of *Drepanocladus crassicostatus*, *D. aduncus* var. *kneiffii*, *D. exannulatus*, *D. aduncus*, *D. revolvens*, *D. vernicosus*, and *D. polycarpus*, as well as *Meesia triquetra*, *Calliergon trifarum*, *C. stramineum*, and *C.*

Table 3

ELK ISLAND RADIOCARBON DATES - Relative to 1950

Wetland Type	Site	Position in Transect	Depth (cm)	Lab. No.	C-14 Age (BP)	Depth Dated	Peat Type Dated	Accumulation Rate
Bog	27	Center	190-195	1020C	2620+/-130	0-195	Poor fen/fen bound.	.73 mm/yr.
	27	Center	295-300	817C	4670+/-200	196-300	Aquatic/limnic.	.49 mm/yr.
	27	Midway	164-169	819C	3510+/-100	0-169	Aquatic/limnic.	.47 mm/yr.
	27	Edge	100-104	820C	1690+/-100	0-104	Fen	.60 mm/yr.
Bog	22	Center	201-211	1022C	4080+/-160	0-211	Aquatic/limnic	.50 mm/yr.
	22	Midway	171-180	1021C	4910+/-110	0-180	Aquatic/limnic	.36 mm/yr.
Mod.-rich Fen	2	Center	415-420	726C	5620+/-130	0-420	Aquatic/limnic	.74 mm/yr.
	2	Midway	545-550	812C	6720+/-120	0-550	Aquatic/limnic	.81 mm/yr.
	2	Edge	477-480	813C	5740+/-240	0-480	Aquatic/limnic	.83 mm/yr.
Mod.-rich Fen	3	Center	460-465	1025C	5560+/-110	0-465	Aquatic/limnic	.83 mm/yr.
	3	Midway	290-295	815C	4780+/-140	0-295	Aquatic/limnic	.61 mm/yr.
	3	Edge	165-170	816C	3270+/-100	0-170	Aquatic/limnic	.51 mm/yr.
Shallow Marsh	35	Center	135-140	821C	4250+/-260	0-140	Aquatic/limnic	.32 mm/yr.
	35	Edge	117-125	1019C	2880+/-140	0-125	Aquatic/limnic	.42 mm/yr.
Swamp	48	Center	220-225	823C	4990+/-230	0-225	Aquatic/limnic	.45 mm/yr.
	48	Midway	205-210	1024C	5310+/-90	0-210	Aquatic/limnic	.39 mm/yr.
	48	Edge	56-70	825C	2910+/-240	0-70	Aquatic/limnic	.20 mm/yr.

Table 3 outlines the location of the peat cores, the depth and type of peat material dated, and the relative accumulation rate.
BP = Years before 1950, Lab. No. = Laboratory Number, Mod.-rich = Moderate-rich, Bound. = Boundary.

Figure 3.

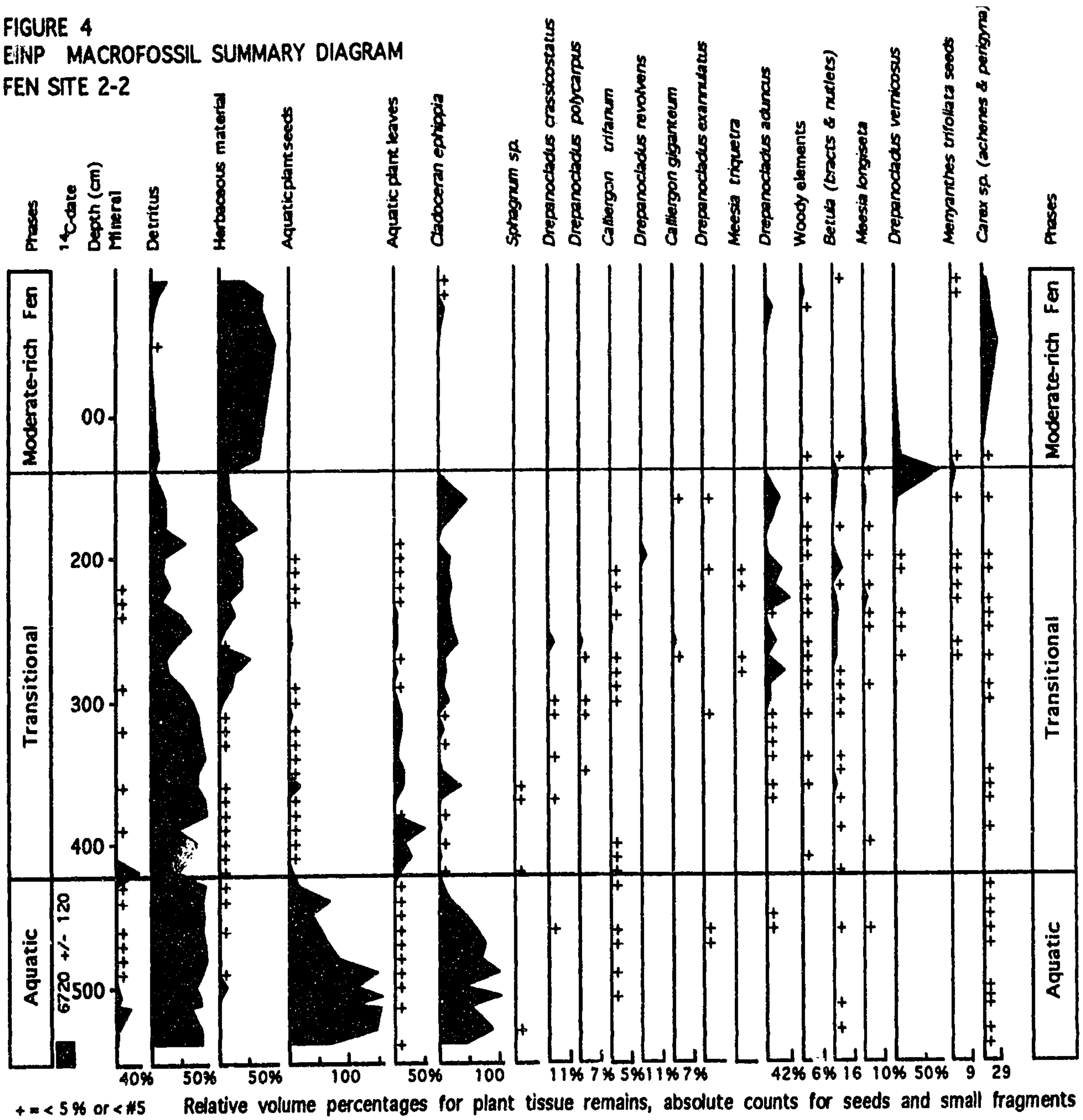
Elk Island National Park Macrofossil Profile, Fen Site 2-1. Located in back pocket.

giganteum are present. The remains of aquatic plants (*Potamogeton, Ceratophyllum*), are still prevalent in these strata and seeds of the aquatic plants *Ranunculus sceleratus*, and *Najas flexilis* are common. Seeds of semi-terrestrial plants (*Menyanthes trifoliata, Triglochin maritima, Carex* sp.) appear at 250 cm. A distinct change occurs in the peat profile at 150 cm. Detritus values decline, corresponding to an increase in herbaceous roots, herbaceous material, *Meesia triquetra, M. longiseta, Calliergon trifarum, C. stramineum, C. giganteum, Carex limosa/paupercula*, and *Carex* sp. achenes.

Core 2-2

Basal sediments of core 2-2 at 550 cm, are radiocarbon dated at 6720 +/- 120 yBP (Fig. 4). Seeds of the aquatic plants (*Chenopodiaceae, Scirpus* sp., *Zannichella palustris, Typha* sp., *Potamogeton* sp., *Ceratophyllum demersum, Ranunculus sceleratus*) are the predominant macrofossils in the basal peat sediments (Appendix I). Cladoceran ephippia reach the highest porportions as well as ostracod and gastropod shells. Above 420 cm, aquatic seeds and cladoceran ephippia numbers decline abruptly and fossil remains of *Drepanocladus crassicostatus, D. polycarpus, D. revolvens, D. exannulatus, D. aduncus, D. vernicosus, Calliergon trifarium, C. giganteum*, and *Meesia triquetra* appear. At 130 cm herbaceous material, herbaceous roots, and the number of *Carex* seeds sharply increase, corresponding to a decline in detritus and cladoceran ephippia.

FIGURE 4
EINP MACROFOSSIL SUMMARY DIAGRAM
FEN SITE 2-2



Core 2-3

The radiocarbon date at 480 cm is 5740 +/- 240 yBP (Fig. 5). Sediments at this depth are dominated by aquatic plant leaves (*Myriophyllum sp., Ceratophyllum demersum, Potamogeton* sp., aquatic plant seeds (*Zannichella palustris, Ceratophyllum demersum, Scirpus* sp., *Ranunculus sceleratus*, *Typha* sp., *Myriophyllum* sp., *Rumex* sp.), *Chara* oospores, cladoceran ephippia, and ostracod shells (Appendix I). Above 225 cm, leaves of the bryophytes *Drepanocladus crassicostatus, D. aduncus, Meesia triquetra* and *M. longiseta* appear. Seeds of the semi-terrestrial *Menyanthes trifoliata* also appear and there is an increase in the amount of *Betula* and woody elements. Above 115 cm the amount of herbaceous material increases substantially while aquatic plants and cladoceran ephippia decline. In these strata the remains of *Drepanocladus vernicosus, D. revolvens* and *Rhizomnium pseudopunctatum* can be found.

Site 3, Core 3-1

Basal peats at core 3-1 are 465 cm deep, 5560 years old, and contain the remains of aquatic seeds (*Scirpus* sp., *Zannichella palustris, Ceratophyllum demersum*, *Ranunculus sceleratus*), ostracod and gastropod shells, *Chara* sp. oospores, and cladoceran ephippia (Fig. 6). Above 375 cm, leaves and seeds of the aquatic plants *Myriophyllum sp., Ceratophyllum demersum*, and *Potamogeton* become prevalent, as well as the bryophytes *Drepanocladus aduncus*, *D. aduncus* var. *kneiffii, D. crassicostatus, Calliergonella cuspidata*, and *Sphagnum* sp. Seeds of semi-terrestrial plants such as *Menyanthes trifoliata*, *Carex*

FIGURE 5
EINP MACROFOSSIL SUMMARY DIAGRAMS
FEN SITE 2-3

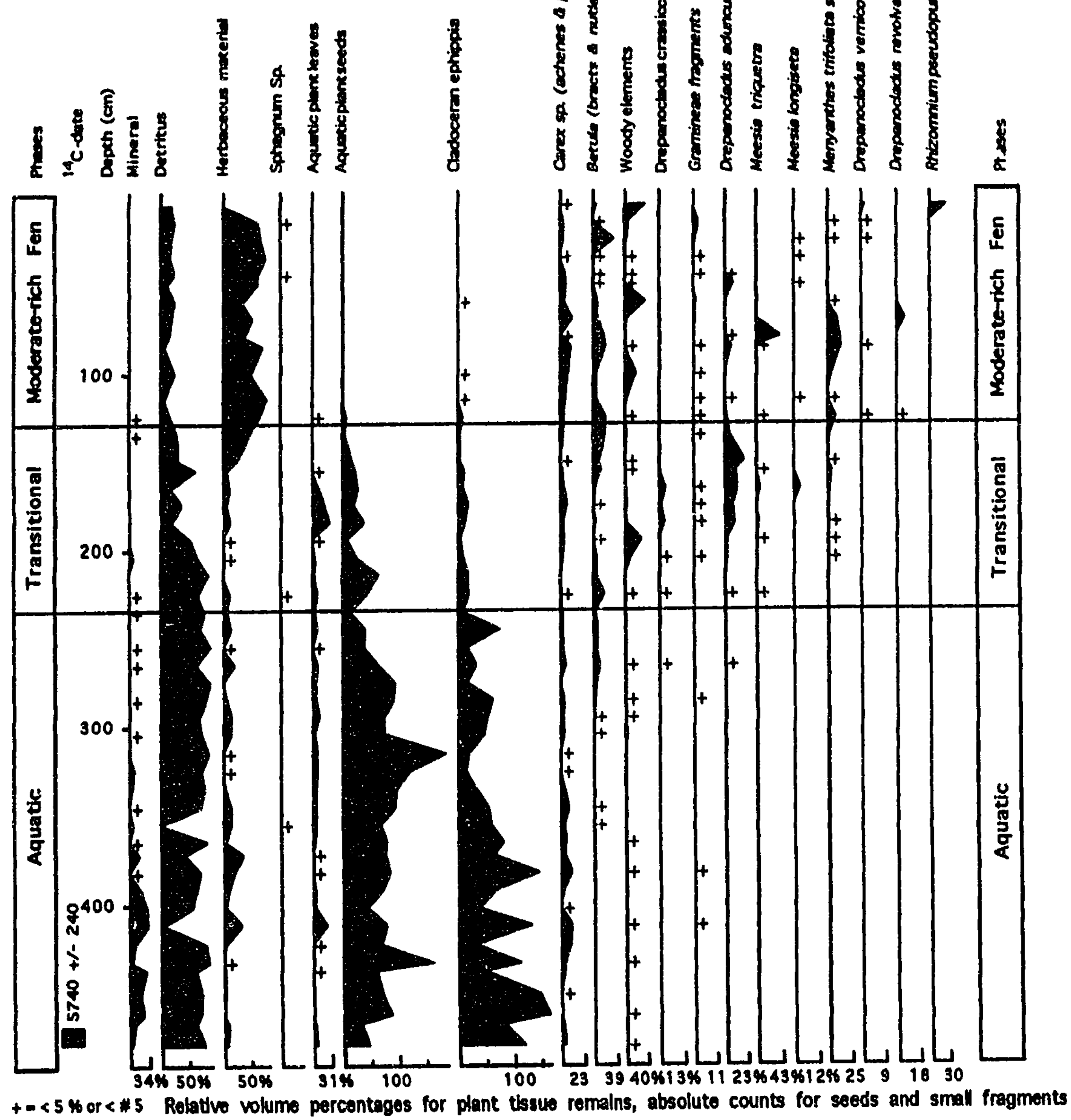


Figure 6.

Elk Island National Park Macrofossil Profile, Fen Site 3-1. Located in back pocket.

sp., and the terrestrial species *Betula* are also present. Incorporation of mineral grains into the peat sediments decreases above 80 cm and in this region, herbaceous material becomes increasing important, while aquatic plants and cladoceran ephippia decline. Above 40 cm, *Calliergon stramineum, Aulacomnium palustre* and *Drepanocladus vernicosus* codominate in the peat assemblage along with herbaceous material and *Carex* sp. achenes.

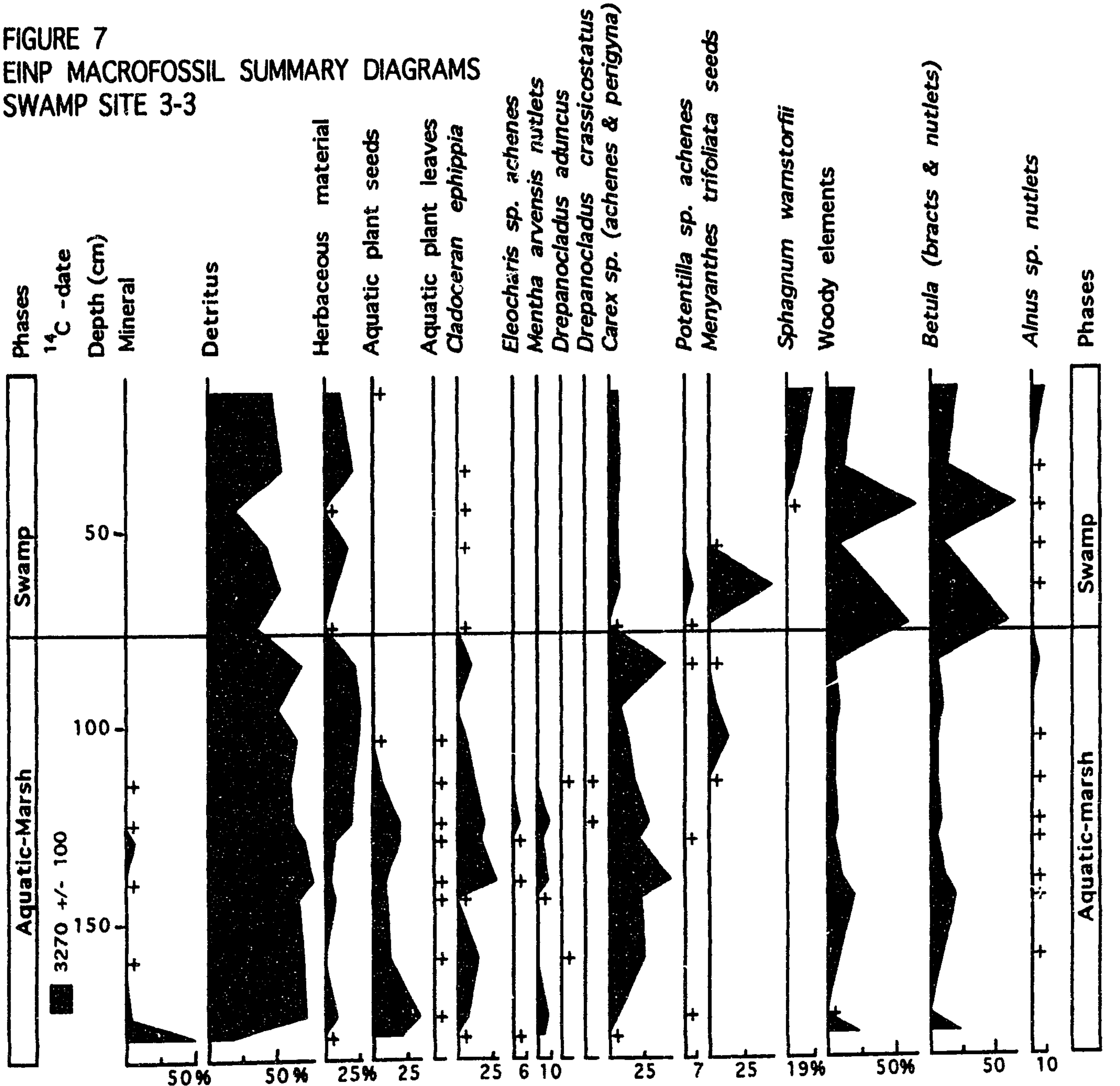
Core 3-3

At 170 cm, the basal peats of core 3-3 are 3270 +/- 100 years old. Dominating these peats are aquatic plant seeds (*Typha* sp., *Myriophyllum* sp., *Ceratophyllum demersum, Ranunculus sceleratus, Najas flexilis* (Appendix I), and cladoceran ephippia (Fig. 7). In addition to the aquatic plants, there are propagules and remains of terrestrial and semi-terrestrial plants (*Mentha arvensis, Potentilla, Carex, Betula*, and *Alnus*). Herbaceous material is more abundant than in the basal sediments of core 3-1. Bryophyte remains include *Drepanocladus aduncus* and *D. crassicostatus*. Above 96 cm, aquatic seeds and cladoceran ephippia decline, while semi-terrestrial and terrestrial elements rise (*Carex* sp., *Potentilla* sp., *Sphagnum warnstorfii*). Particularly dominant in these sediments are materials of a woody nature (woody elements, *Betula* bracts and nutlets, and *Alnus* nutlets).

Site 22, Core 22-1

Four thousand and eighty years before present, aquatic plants and cladoceran ephippia began to accumulate in the basin of site 22 (Fig.

FIGURE 7
EINP MACROFOSSIL SUMMARY DIAGRAMS
SWAMP SITE 3-3



+ = < 5 % or < # 5 Relative volume percentages for plant tissue remains, absolute counts for seeds and small fragments

8). Leaves and microscopic remains of *Carex* sp., *Betula* sp., *Sphagnum warnstorfii*, S. *centrale*, *S. capillifolium*, *S. russowii*, and *Polytrichum strictum* were deposited. Above 129 cm the remains of aquatic plants decline and semi-terrestrial plants (*Carex* sp., *Betula* sp., *Sphagnum* spp.) dominate. Recent peat sediments are dominated by *Sphagnum capillifolium*, woody elements, *S. russowii*, and *Polytrichum strictum.*

Core 22-2

Peat depth at core 22-2 is shallower, but older (4910 yBP) than core 22-1. Mineral grains comprise the greatest portion of the basal sediments (Fig. 9). Farther up the peat profile, detritus and aquatic plants dominate with fragments of *Drepanocladus aduncus*, *Sphagnum magellanicum*, and *S. russowii.* A transitional aquatic/terrestrial phase occurs above 90 cm. Aquatic seeds and cladoceran ephippia are still present in the sediments, but herbaceous material has increased and seeds of the terrestrial herbs (*Sium sauve*, *Potentilla* sp., *Carex* sp., *Betula* sp.) occur. This section is followed by sediments dominated by *Sphagnum*, *Ledum groenlandicum*, *Carex* sp., woody elements, and *Betula* sp. Near the surface, the peat community abruptly changes to one dominated by herbaceous material, *Polytrichum strictum*, and *Calliergon stramineum.*

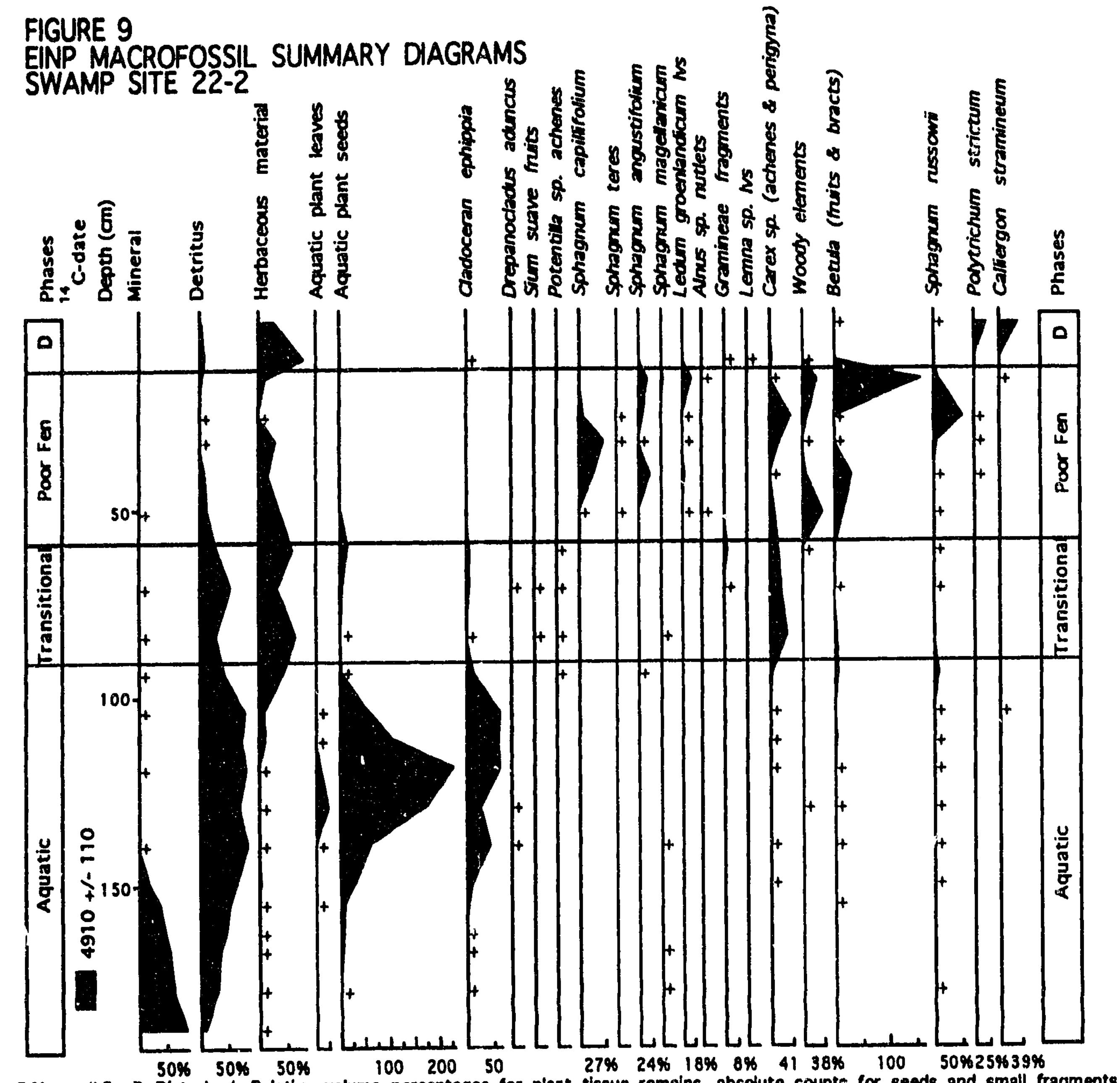
Core 22-3

The earliest peat forming community at core 22-3 was aquatic in nature, formed by aquatic plants, herbs and Cladocera (Fig. 10).

Figure 8.

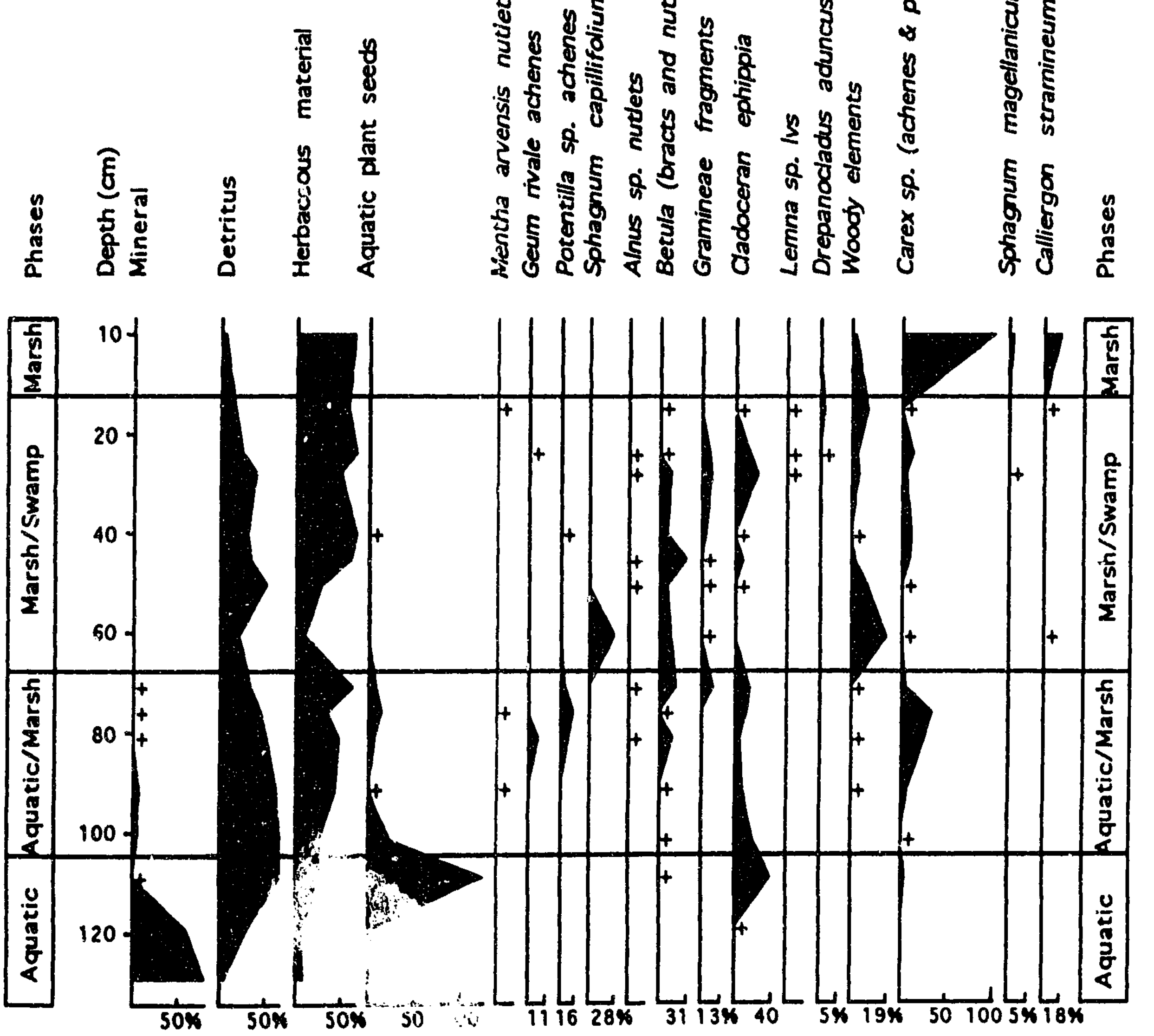
Elk Island National Park Macrofossil Profile, Bog Site 22-1. Located in back pocket.

FIGURE 9
EINP MACROFOSSIL SUMMARY DIAGRAMS
SWAMP SITE 22-2



+ = < 5 % or < # 5 D=Disturbed Relative volume percentages for plant tissue remains, absolute counts for seeds and small fragments

FIGURE 10
EINP MACROFOSSIL SUMMARY DIAGRAMS
MARSH SITE 22-3



+ = < 5 % or < # 5 Relative volume percentages for plant tissue remains, absolute counts for seeds and small fragments

Mineral grains are frequently mixed with the peat sediments. Farther up the peat profile, herb percentages increase, along with terrestrial species such as *Mentha arvensis, Geum rivale, Potentilla, Alnus* sp., *Betula* sp, Gramineae, woody elements, and *Carex* sp. In strata above 70 cm, aquatic plants decline, while *Sphagnum capillifolium, Drepanocladus aduncus, Carex* sp., and *Betula* sp. increase. In the top 20 cm of peat, *Carex* sp., and herbaceous material dominate along with *Sphagnum magellanicum* and *Calliergon stramineum.*

Site 27, Core 27-1

The aquatic macrofossils that comprise the basal peats at core 27-1 are 4670 +/- 200 years old, and are slightly different from the previous sites in that only a few aquatic species are present and in small amounts (Fig. 11). These consist predominantly of the leaves and seeds of *Myriophyllum* sp., *Ceratophyllum demersum, Potamogeton* sp., *Typha* sp., *Najas flexilis, Ranunculus sceleratus*, and *R. circinatus*. A high number of semi-terrestrial species are also present in these basal sediments (*Drepanocladus aduncus* var. *kneiffii, D. exannulatus, Calliergon stramineum, Sphagnum* section Cuspidata, *S. magellanicum, Caltha palustris, Menyanthes, Carex,* and *Betula*). Above 240 cm there is a dramatic increase in the quantity of herbaceous roots, and herbaceous material as well as an increase in the quantity of bryophyte remains (*Drepanocladus aduncus, D. vernicosus, Calliergon stramineum,* and *Tomenthypnum nitens*), and *Betula* nutlets. This is followed by a lengthy section of peat that is dominated by members of the genus *Sphagnum* (*S. magellanicum, S.*

Figure 11.

Elk Island National Park Macrofossil Profile, Bog Site 27-1. Located in back pocket.

angustifolium, S. warnstorfii, S. capillifolium), ectomycorrhizal roots, *Picea* needles and fungal mycelia. Surficial peats are comprised of only a few Sphagnum species (*S. magellanicum, S. fuscum*) and *Polytrichum strictum*.

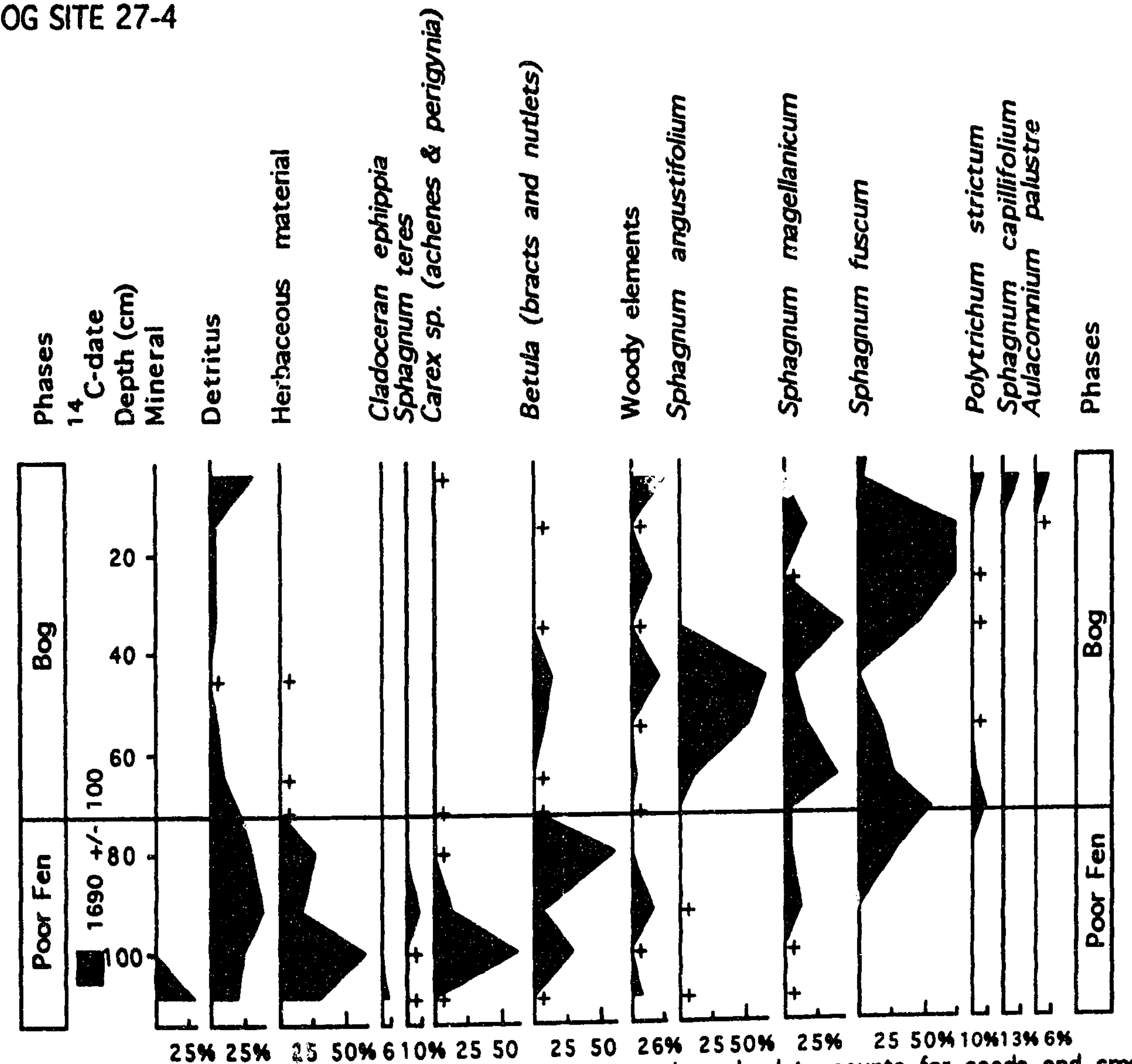
Core 27-4

The basal sediments of core 27-4 are the youngest found in this study (1690 +/- 100 yBP, Fig. 12). Contrary to all previous cores, this core does not contain aquatic plants, or seeds of aquatic plants, in the basal sediments. The initial peat forming community is dominated by herbs, *Carex* sp., *Betula* sp., woody elements, and small amounts of *Sphagnum teres, S. angustifolium* and *S. fuscum. Sphagnum* dominance occurs above 72 cm; predominant are the species *Sphagnum fuscum, S. magellanicum*, and *S. angustifolium.*

Site 35, Core 35-1

Sediments at core 35-1 are shallow, and date to 4250 +/- 260 yBP (Fig. 13). Mineral grains are prominent in these basal sediments. Remains of aquatic plants are present, particularly those of *Chara*, and *Typha* sp., along with cladoceran ephippia. Above 59 cm, the remains of aquatic plants disappear and herbaceous material, herbaceous roots, *Betula* sp., and *Carex* sp., increase. No bryophytes are present in this upper phase and all categories describing woody elements remain low, indicating a herbaceous/*Carex* community.

FIGURE 12
EINP MACROFOSSIL SUMMARY DIAGRAMS
BOG SITE 27-4



+ = < 5 % or < # 5 Relative volume percentages for plant tissue remains, absolute counts for seeds and small fragments

Figure 13.

Elk Island National Park Macrofossil Profile, Marsh Site 35-1. Located in back pocket.

Core 35-2

The peat profile at core 35-2 is younger (2880 +/- 140) and shallower (136 cm) than core 35-1 (Fig. 14). Once again aquatic sediments are present at the base. These consist predominantly of *Chara* oospores, *Potamogeton* sp., *Typha* sp., *Eleocharis* sp., and *Ranunculus* sp. seeds (Appendix I). Incorporated into the peat is a high percentage of mineral grains, and the seeds of *Potentilla* sp., *Mentha arvensis*, *Betula* sp., and *Carex* sp. Gradually the aquatic species decline and herbaceous material dominates with Gramineae fragments and *Carex* sp. achenes.

Core 35-3

Core 35-3 is shallow with just 45 cm of peat (Fig. 15). Again there are mineral grains and aquatic seeds, especially *Typha* sp. present in the basal portion (Appendix I). Charcoal fragments are abundant in this core. Herbaceous material and Gramineae fragments increase towards the surface.

Site 48, Core 48-1

Peat began to accumulate in the shallow bay of a lake at this site around 4990 +/- 230 yBP. (Fig. 16). Mineral grains are frequently mixed with the peaty substrate. Leaves and seeds of the aquatic plants *Myriophyllum* sp., *Ceratophyllum demersum*, *Ruppia maritima*, *Typha* sp., *Scirpus* sp., and the oospores of *Chara* and cladoceran ephippia are found in these layers. Above 150 cm, aquatic plants and cladoceran ephippia decline, while herbaceous roots,

FIGURE 14
EINP MACROFOSSIL SUMMARY DIAGRAMS
SHALLOW MARSH SITE 35-2

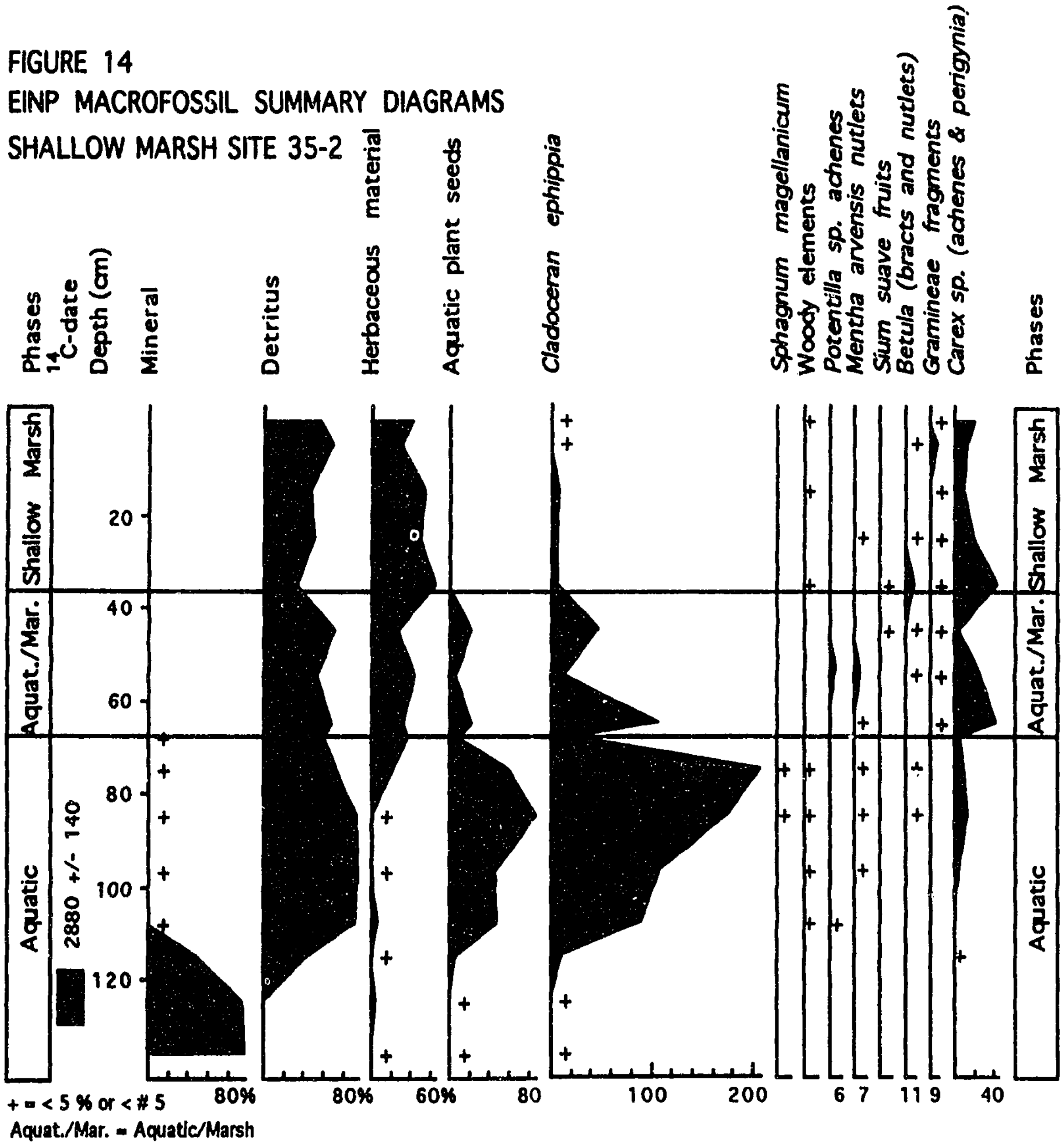
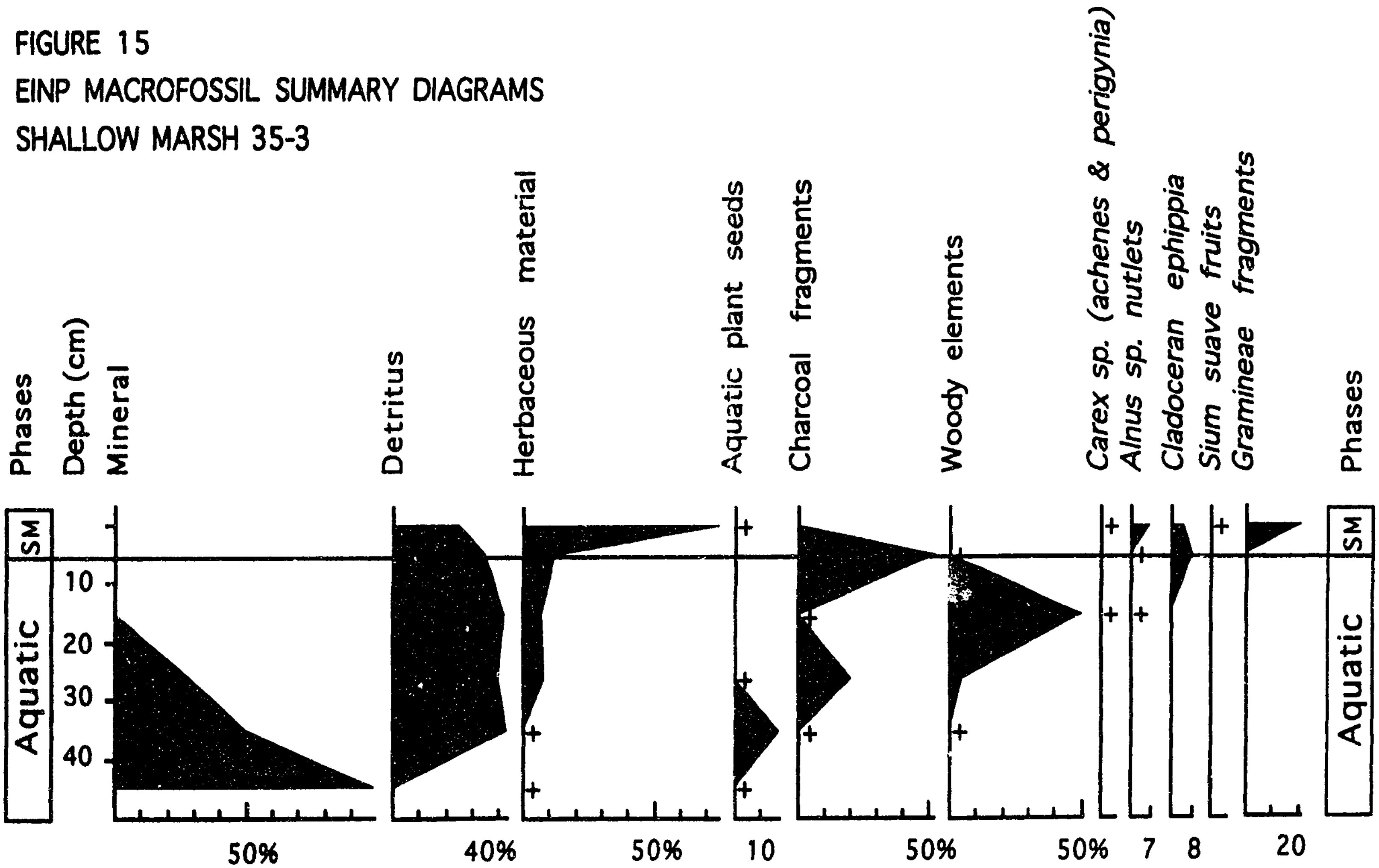


FIGURE 15

EINP MACROFOSSIL SUMMARY DIAGRAMS

SHALLOW MARSH 35-3



+ = < 5 % or < # 5 Relative volume percentages for plant tissue remains, absolute counts for seeds and small fragments

SM = Shallow Marsh

Figure 16.

Elk Island National Park Macrofossil Profile, Marsh Site 48-1. Located in back pocket.

Ranunculus sceleratus and *Carex* sp. achenes increase. In the third phase, above 25 cm, an abrupt increase in *Larix* and *Picea* needles, deciduous leaves and ectomycorrhizal roots occurs. This is followed by a return to sediments dominated by herbaceous components.

Core 48-3

Peat began to accumulate in this portion of the basin much later (2910 +/- 240 yBP) than cores 48-1 and 48-2 (Fig. 17). Mineral grains were incorporated into these initial sediments. Few aquatic macrofossils are present, consisting of the achenes of *Typha* sp., *Juncus* sp., and *Ranunculus sceleratus*. (Appendix I). Fossils of terrestrial plants (*Mentha arvensis*, *Betula*, woody elements) are present as well. Farther up the peat profile, herbaceous material, *Carex* achenes, and woody elements all increase. The most recent peat sediments are dominated by woody elements, with minor amounts of *Carex* achenes.

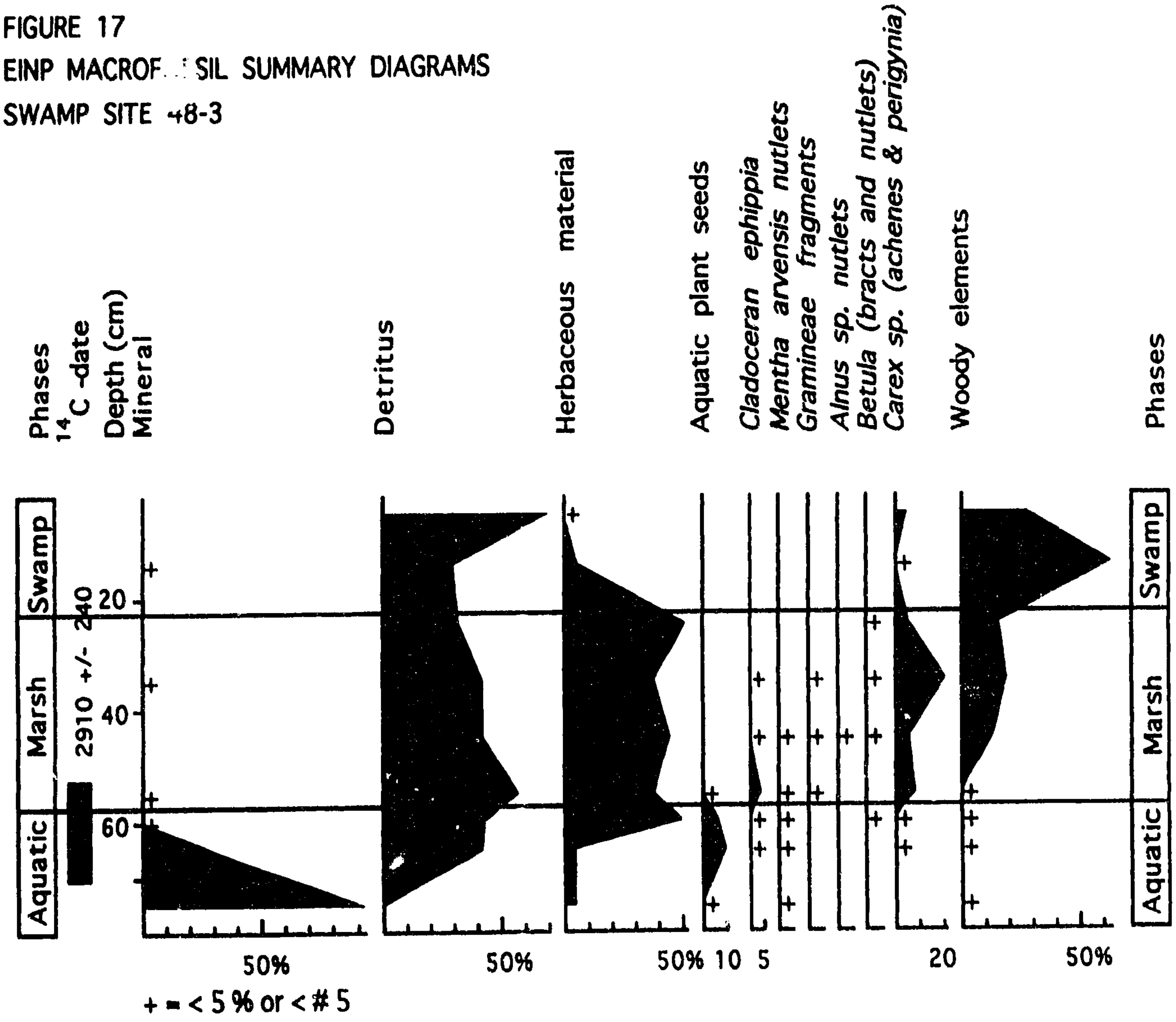
Peat Chemistry

Peat samples were assigned to one of eight peat types based on the peat phase identified in the macrofossil analysis and subjected to a canonical correlation and discriminant analysis. Peat type categories are based upon the macrofossil analysis: **aquatic**- limnic peat containing seeds and fossils of aquatic plants; **transitional**- limnic peat containing the remains of aquatic and fen plants; **marsh**- telmatic peat containing herbaceous plant remains; **swamp**- telmatic peat containing herbaceous and woody macrofossils; **aquatic/marsh/swamp**- peat containing a mixture of the three

FIGURE 17

EINP MACROFOSSIL SUMMARY DIAGRAMS

SWAMP SITE 48-3



described above; **moderate-rich fen**- terrestric peat containing fossil bryopytes of the family Amblystegiaceae; **poor fen**- terrestric peat dominated by *Sphagnum* species but also containing the family Amblystegiaceae; and **bog**- terrestric peat dominated by *Sphagnum* macrofossils. The canonical discriminant analysis derives a linear combination of variables that has the highest correlation within the given groups. Multivariate statistics and F approximations test the hypothesis that the class means are equal in the population. Each of the multivariate statistics is significant at the 0.0001 level indicating that these categories are significantly different (Table 4).

A graph of the class means for each peat type on the first two canonical axes shows the relative similarities between peat types. Peats that contain aquatic sediments are situated on the right side of the X axis, while marsh, swamp, fen and bogs peats are on the left (Fig. 18). According to the canonical coefficients (Table 5) the most discriminating variable on the X axis is percentage ash followed by depth. The Y axis is most strongly discriminated by site number, indicating that peat chemistry is extremely site specific. Table 6 shows the percentage of samples placed into the correct peat type category by the discriminant analysis. Most peat type categories are well defined chemically as each peat type category was correctly placed between 77-100% of the placements. The exception is peat type aquatic/marsh/swamp which contains elements of all three peat types. Two samples were placed into the adjacent marsh category, one into the aquatic category, and another into the bog category.

Table 4

Canonical Discriminant Analysis
Multivariate Statistics and F Approximations

Statistic	Value	F	Numerator Degrees of Freedom	Denominator Degrees of Freedom	Prob > F
Wilks' Lambda	0.0103	13.78	133	1834	0.0001
Pillai's Trace	2.9591	10.87	133	1974	0.0001
Hotelling-Lawley Trace	8.1948	16.9	133	1920	0.0001
Roy's Greatest Root	3.373	50.06	19	282	0.0001

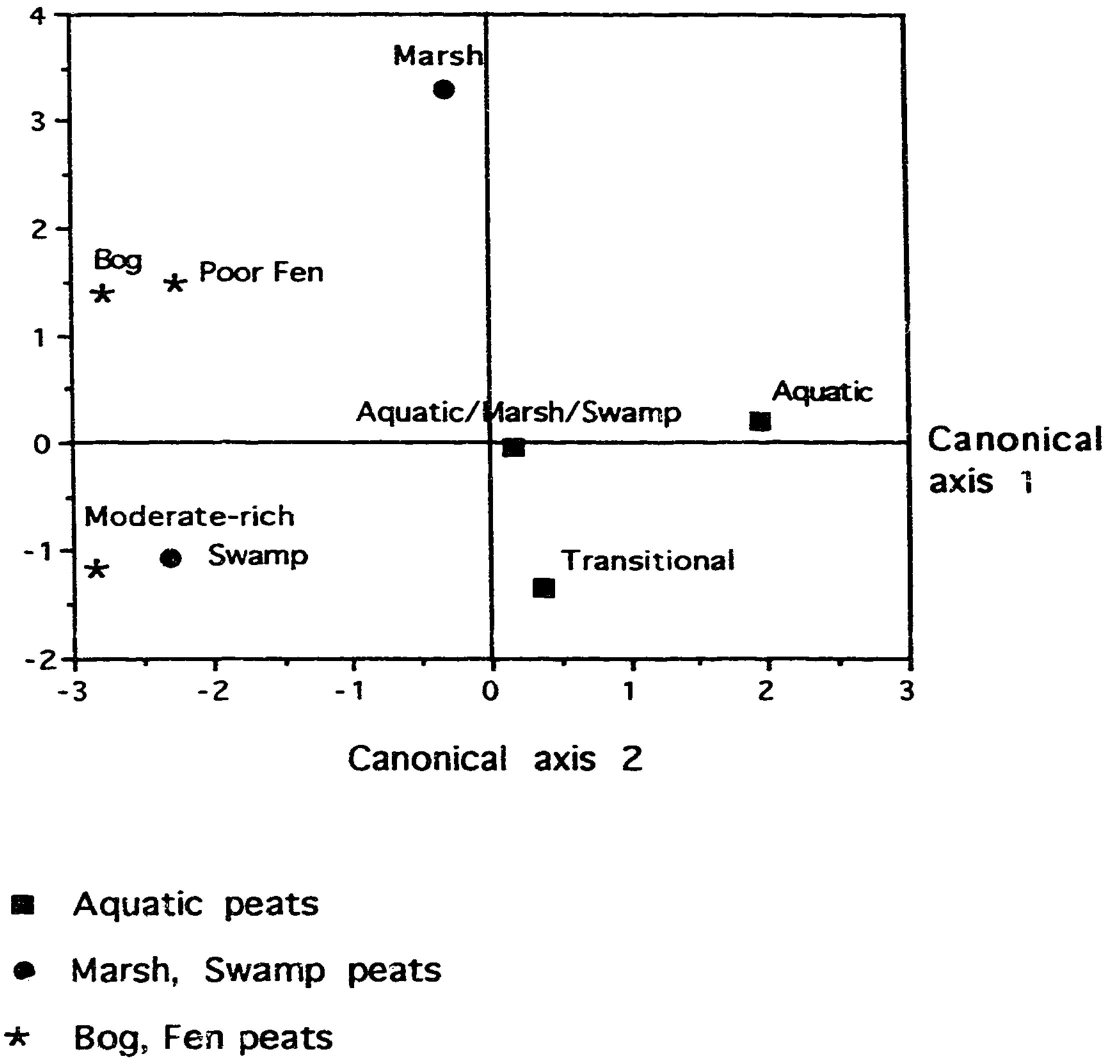


Fig. 18. Outlines the relationship in discriminant space between peat types based on canonical class means of chemical variables plotted on the first two canonical axis.

Table 5

Canonical Discriminant Analysis
Total-Sample Standardized Canonical Coefficients

	Canonical Axis 1	Canonical Axis 2
Site	0.64	1.70
Core	0.05	0.17
Depth	-0.80	-1.18
Calcium	0.02	0.18
Magnesium	0.03	-0.17
Potassium	0.16	0.45
Aluminum	-0.01	0.15
Titanium	0.00	0.15
Lead	-0.14	0.13
Arsenic	0.09	-0.41
Copper	-0.24	0.13
Iron	0.25	-0.47
Manganese	-0.27	-0.64
Zinc	0.33	-0.20
Nickel	0.06	0.08
Phosphorus	-0.01	0.24
Sulphur	0.40	0.15
Ash	1.24	-0.65
Bulk density	0.03	0.07

Table 6
Discriminant Analysis

Into Peat Type

From Peat Type	Aquatic	Transitional Aq/Fen	Marsh	Aq/Mar/Sw	Swamp	Mod-rich Fen	Poor Fen	Bog	Total
Aquatic	75 77.3%	10 10.3%	4 4.1%	3 3.1%	0 0%	0 0%	5 5.2%	0 0%	97 100%
Transitional (Aquatic/Fen)	5 6.3%	65 82.3%	4 5.1%	2 2.53%	0 0%	3 3.8%	0 0%	0 0%	79 100%
Marsh	0 0%	0 0%	32 100%	0 0%	0 0%	0 0%	0 0%	0 0%	32 100%
Aquatic/Marsh/Swamp	1 11.1%	0 0%	2 22.2%	4 44.4%	1 11.1%	0 0%	0 0%	1 11.1%	9 100%
Swamp	0 0%	0 0%	1 14.3%	0 0%	5 71.4%	1 14.3%	0 0%	0 0%	7 100%
Moderate-rich Fen	0 0%	3 7.1%	0 0%	0 0%	1 2.4%	36 85.7%	1 2.4%	1 2.4%	42 100%
Poor Fen	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	19 82.6%	4 17.4%	23 100%
Bog	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	3 23.1%	10 77%	13 100%
Total	81 26.8%	78 25.8%	43 14.2%	9 3%	7 2.3%	40 13.3%	28 9.3%	16 5.3%	302 100%

Aq=Aquatic, Mar=Marsh, Sw=Swamp, Mod=Moderate
Absolute number of samples and relative percentage of peat samples correctly placed in the assigned peat type by SAS Discriminant Procedure.

Aquatic peats are characterized by high ash (66%), bulk density (0.62 g/cm^3), calcium (28,737 mg/Kg), magnesium (3,373 mg/Kg), and potassium (2,162 mg/Kg, Table 7). Aluminum, iron, manganese, and nickle concentrations are high, while phosphorus and sulphur concentrations are intermediate.

Transitional peats that contain both aquatic and fen sediments are intermediate between the two peat types in ash content, bulk density, magnesium, sodium, potassium, aluminum, lead, arsenic, manganese, zinc, nickle and phosphorus. This group is higher than aquatic or moderate-rich fen peats in sulphur.

Aquatic/Marsh/Swamp peats have high ash (33%), bulk density (0.44 g/cm^3), calcium (22,075 mg/Kg), magnesium (2,347 mg/Kg), potassium (1,506 mg/Kg), sodium (646 mg/Kg), aluminum (4,811 mg/Kg), titanium (40 mg/Kg), copper (9 mg/Kg), and zinc (121 mg/Kg)(Table 7). In comparison to other peat types, phosphorus and sulphur levels are average having 866 mg/Kg P and 6,654 mg/Kg S respectively.

Marsh peats at Elk Island National Park have the highest calcium (34,480 mg/Kg) and sodium (1,862 mg/Kg) contents (Table 7). Some elemental concentrations are reduced in this peat type as compared to other peats experiencing groundwater input (Fe 3,929 mg/Kg, Mn 82 mg/Kg, Zn 72 mg/Kg, Ni 12 mg/Kg). Sulphur and phosphorus levels are the highest in this peat type at 12,293 mg/Kg and 1,092 mg/Kg, respectively. Bulk density and ash content of this group are relatively low at 0.15 g/cm^3 and 19%.

Swamp peats have intermediate ash percentages (13%), and bulk density values (0.14 g/cm^3), but high concentrations of calcium

Table 7
Peat Chemistry

Chemical and Physical Variables	Peat type															
	Aquatic		Transitional (Aquatic/Fen)		Aq./Marsh/Swamp		Marsh		Swamp		Moderate-rich Fen		Poor Fen		Bog	
Ca (mg/Kg)	28,737	29,084	18,383	16,522	22,075	16,622	34,480	12,747	28,392	6,766	9,766	3,140	7,012	3,277	4,660	1,910
Mg	3,373	1,686	2,298	657	2,347	1,506	2,409	416	2,980	270	2,193	1,481	857	503	870	263
K	2,162	1,006	1,387	584	1,506	1,359	669	1,038	475	549	1,159	1,661	364	580	924	1,011
Na	477	404	210	77	646	975	1,862	1,205	516	1,114	197	112	86	80	107	45
Al	10,107	4,799	6,888	2,500	4,821	4,132	2,735	1,983	1,883	1,127	2,198	2,370	2,320	4,068	1,401	818
Ti	25	18	16	9	40	36	28	13	30	14	13	5	15	5	11	3
Pb	16	10	14	6	7	6	5	6	3	1	7	8	8	6	11	16
As	17	7	14	5	9	8	5	3	5	1	4	3	4	5	3	1
Cu	9	4	5	2	9	56	10	6	6	2	3	3	4	3	4	2
Fe	10,014	3375	12,632	6506	5,357	3,863	3,929	2,285	6,323	4,012	2,521	1,630	2,569	2,709	1,585	873
Mn	355	300	339	215	182	244	82	74	203	169	225	309	55	56	128	188
Zn	71	35	99	55	121	69	72	64	63	56	51	46	22	13	36	16
Ni	20	22	18	20	13	7	12	22	8	3	8	13	5	6	6	5
P	603	249	921	476	866	498	1,092	307	972	464	1,004	484	477	249	583	211
S	7,774	5,220	9,159	5,427	6,654	4,554	12,293	4,204	4,233	3,746	2,688	1,497	1,929	2,096	946	327
% Ash	66	22	35	14	33	27	19	8	13	6	11	11	8	11	6	4
Bulk Density (g/cm^3)	0.62	0.38	0.19	0.13	0.44	0.35	0.15	0.08	0.14	0.06	0.14	0.10	0.12	0.08	0.07	0.04
n	99		84		33		15		8		46		27		17	

Aq. = Aquatic

Mean values plus standard deviations of the chemical and physical variables of peat samples grouped according to peat type.

28,392 mg/Kg), magnesium (2,980 mg/Kg), and sodium (516 mg/Kg) (Table 7). In general elemental concentrations are low, except for titanium (30 mg/Kg) and iron (6,323 mg/Kg). Phosphorus levels are high (972 mg/Kg), while sulphur is intermediate (4,233 mg/Kg).

Moderate-rich fen peats contain low amounts of ash (11%), calcium (9,766 mg/Kg), and sodium (197 mg/Kg, Table 7). Elemental contents are also low, reflecting limited groundwater infiltration (Ti 13 mg/Kg, As 4 mg/Kg, Fe 2,521 mg/Kg, Zn 51 mg/Kg, Ni 8 mg/Kg). Phosphorus, sulphur, and bulk density measurements are higher than the poor fen or bog peats (1,004 mg/Kg, 2,688 mg/Kg, 0.14 g/cm^3)

Poor fen peats are relatively low in ash (8%), calcium (7,012 mg/Kg), magnesium (857 mg/Kg), potassium (364 mg/Kg), sodium (86 mg/Kg), aluminum (2,320 mg/Kg), titanium (15 mg/Kg), Lead (8 mg/Kg), arsenic (4 mg/Kg), copper (4 mg/Kg), iron, (2,569 mg/Kg), Manganese (55 mg/Kg), Zinc (22 mg/Kg), Nickel (5 mg/Kg), phosphorus (477 mg/Kg), sulphur (1,929 mg/Kg), and bulk density (0.12 g/cm^3, Table 7).

Bog peats are low in ash (6%), calcium (4,660 mg/Kg), magnesium (870 mg/Kg), most elements, sulphur (946 mg/Kg), and bulk density (0.07 g/cm^3, Table 7)

According to the results of the discriminant analysis, it is possible to identify peat types based upon peat chemistry. Peats that contain aquatic sediments comprise the first three peat types (aquatic, transitional, aquatic/marsh/swamp). They are most easily segregated from the remaining peat types by differences in ash content and bulk density. Peat that has a component of aquatic sediments generally has an ash content greater than 20% and bulk density greater than 0.15 g/cm^3. Metal concentrations in these peats are characteristically high. Particularly good aquatic indicators appear to be aluminum concentrations greater than 2,735 mg/Kg, arsenic concentrations greater than 5 mg/Kg, iron concentrations greater than 3,929 mg/Kg, zinc concentrations greater than 72 mg/Kg, and nickel concentrations greater than 12 mg/Kg (Table 7).

Marsh and swamp peats are distinguishable from fen and bog peats on the basis of calcium concentrations. Marsh and swamp peats have high calcium values (> 10,000 mg/Kg) and high sodium concentrations compared to fens and bogs (Table 7). Additional elements segregating the two appear to be titanium, copper, zinc, and sulphur. Ash percentages are also usually higher in marsh and swamp peats at Elk Island.

On the basis of peat chemistry it is difficult to distinguish between marsh and swamp peats at Elk Island. Swamps tend to be slightly less mineral rich, reflected in lower calcium, potassium, sodium, ash, and bulk density values, and slightly less nutrient rich reflected in lower phosphorus and sulphur concentrations. Water chemistry parameters confirm that marshes are more ionically rich and more eutrophic than swamps at Elk Island (Table 2).

The chemical parameters that define the gradient segregating bogs from fens has been well documented (Sjörs 1952, Gorham 1956, Jeglum 1971, 1972, Vitt *et al.* 1975, Horton *et al.* 1979, Slack *et al.* 1980, Glaser *et al.* 1981, Sims *et al.* 1982, Karlin and Bliss 1984, Vitt and Chee 1990, Vitt *et al.* 1990). At Elk Island, the fen peats have higher calcium, aluminum, titanium, iron, sulphur, ash, and bulk density than those from bogs (Table 7).

Peat Profiles

The chemistry of organic matter in peat deposits is the result of several processes. Peatlands have different mineral sources depending upon the hydrology of the site (Siegel 1983, 1988, Damman 1986, Siegel and Glaser 1987, Glaser *et al.* 1990). Peat deposits can sequester chemical elements through cation exchange (Malmer and Sjörs 1955, Gorham 1957, Clymo 1963, Yefimov and Yefimova 1973, Damman 1978, 1986, Hemond 1980, Lembrechts and Vanderborght 1985, Bayley *et al.* 1986) and under situations where elements can be transported into peatlands through waterflow, the peat material will become enriched with cations (Mörnsjö 1968, Zoltai and Johnson 1985) or metals (Gleason and Coope 1966, Coker and DiLabio 1979). Compaction and decomposition of the peat material with depth can account for an increase in some elements. It has been suggested by Zoltai and Johnson (1985), that sulphur increases with depth due to retention of the element and the loss of organic material through decomposition. Elements can also be released from a peatland under conditions of redox changes (Bayley *et al.* 1986, Shotyk 1986), and leaching (Damman 1986). Of the several elements analyzed and reported in this study, only calcium and copper, both of which are well known for their strong retention properties in peat (Damman 1986, Shotyk 1986), have been used to study wetland evolution.

Physical Profiles

Percentage Ash

Ash content of peat profiles in the fens at Elk Island National park decline towards the peat surface (Fig. 19). Aquatic peats contain > 40% ash, transitional aquatic/fen peats contain < 40% ash, and moderate-rich fen peats contain less than 15% ash. Ash percentages in peat profiles of the bogs (Fig. 20) experience a rapid decline between aquatic peats containing > 40% to < 20% in the transitional aquatic/fen peats or to < 5% in the poor fen and bog peats. Ash profiles at site 22 are more gradual than site 27. Ash contents in profiles from swamp/marsh wetlands (Fig. 21) decline from > 40% in the aquatic sediments to < 20% in the transitional aquatic/marsh peats. Surface sediments from both wetland types stabilize around an ash content of 10-15%.

Bulk Density

Bulk density profiles in the wetlands of Elk Island National Park (Figs. 22, 23, 24) outline a history of gradual decreasing bulk densities from basal peat to surface peats. Basal aquatic peats in the fen profiles have bulk densities > 0.2 g/cm^3; transitional aquatic/fen peats are lighter (>0.1 g/cm^3); while surface sediments are often denser (up to 0.5 g/cm^3 in cores 2-1, 2-2, 3-1, and 3-2). Aquatic peats in bog site 22 are similar in density to fen peats (> 0.2 g/cm^3), while aquatic peats at site 27 cores 2 and 3 are lighter (0.1-0.2 g/cm^3). Moderate-rich fen and poor fen peats at site 27 have a bulk density of approx. 0.1 g/cm^3, and are variable in core 3. Bulk density measurements of surface peats were unobtainable at site 22, because

Figure 19
Physical Profiles
Percentage Ash-Fens

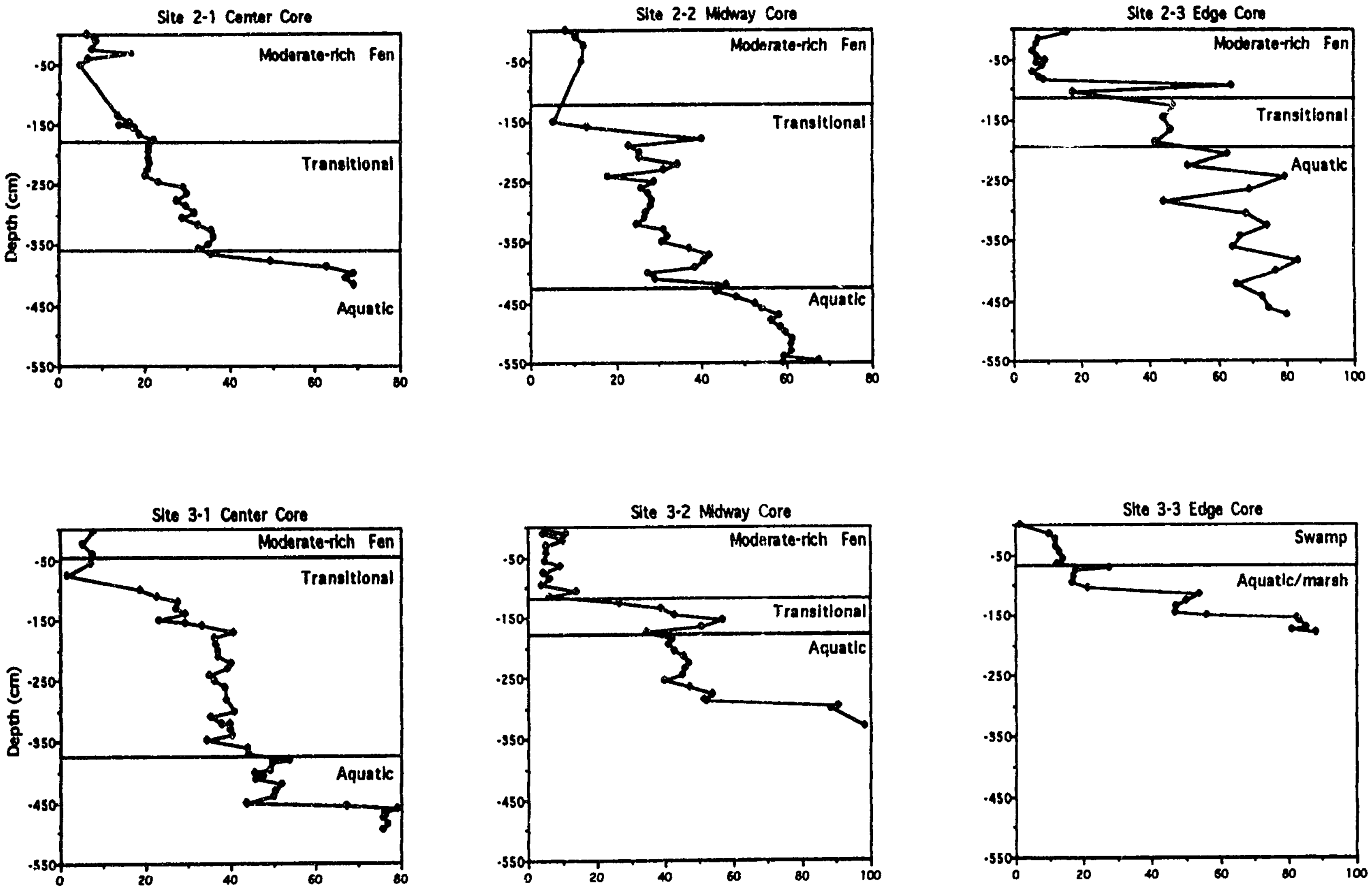


Figure 20
Physical Profiles
Percentage Ash-Bogs

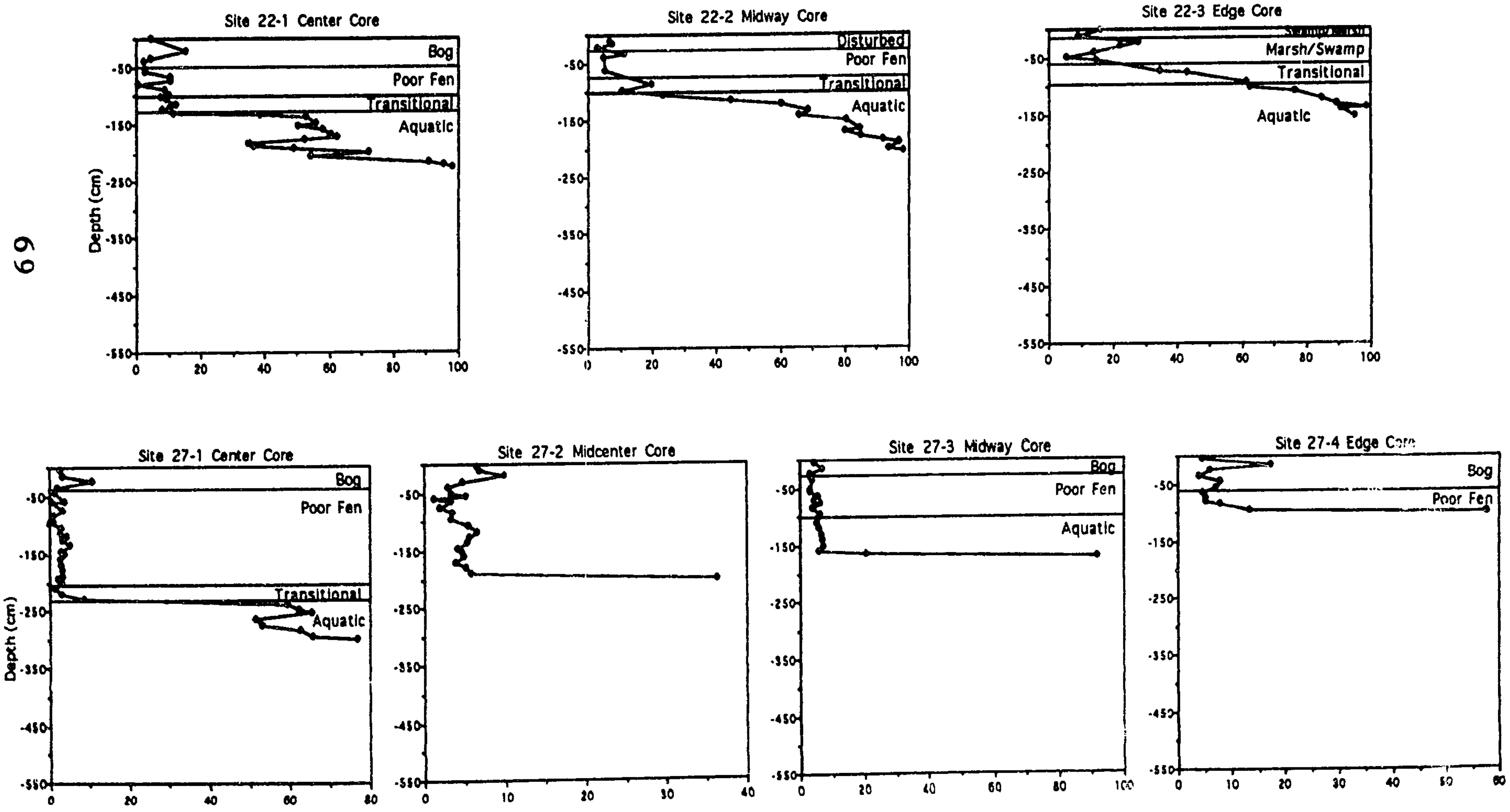


Figure 21
Physical Profiles
Percentage Ash-Marsh/Swamps

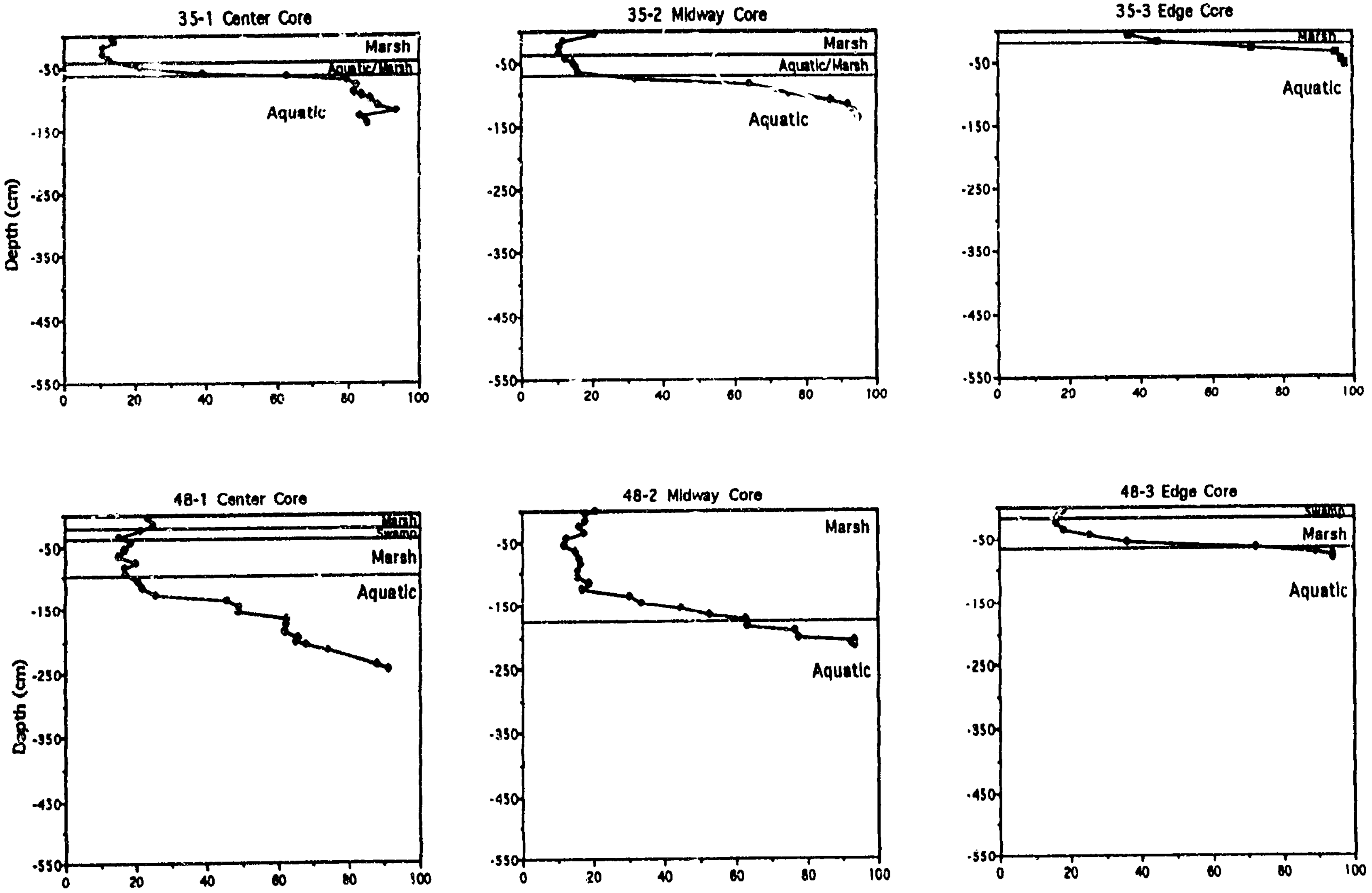


Figure 22
Physical Profiles
Bulk Density-Fens g/cm^3

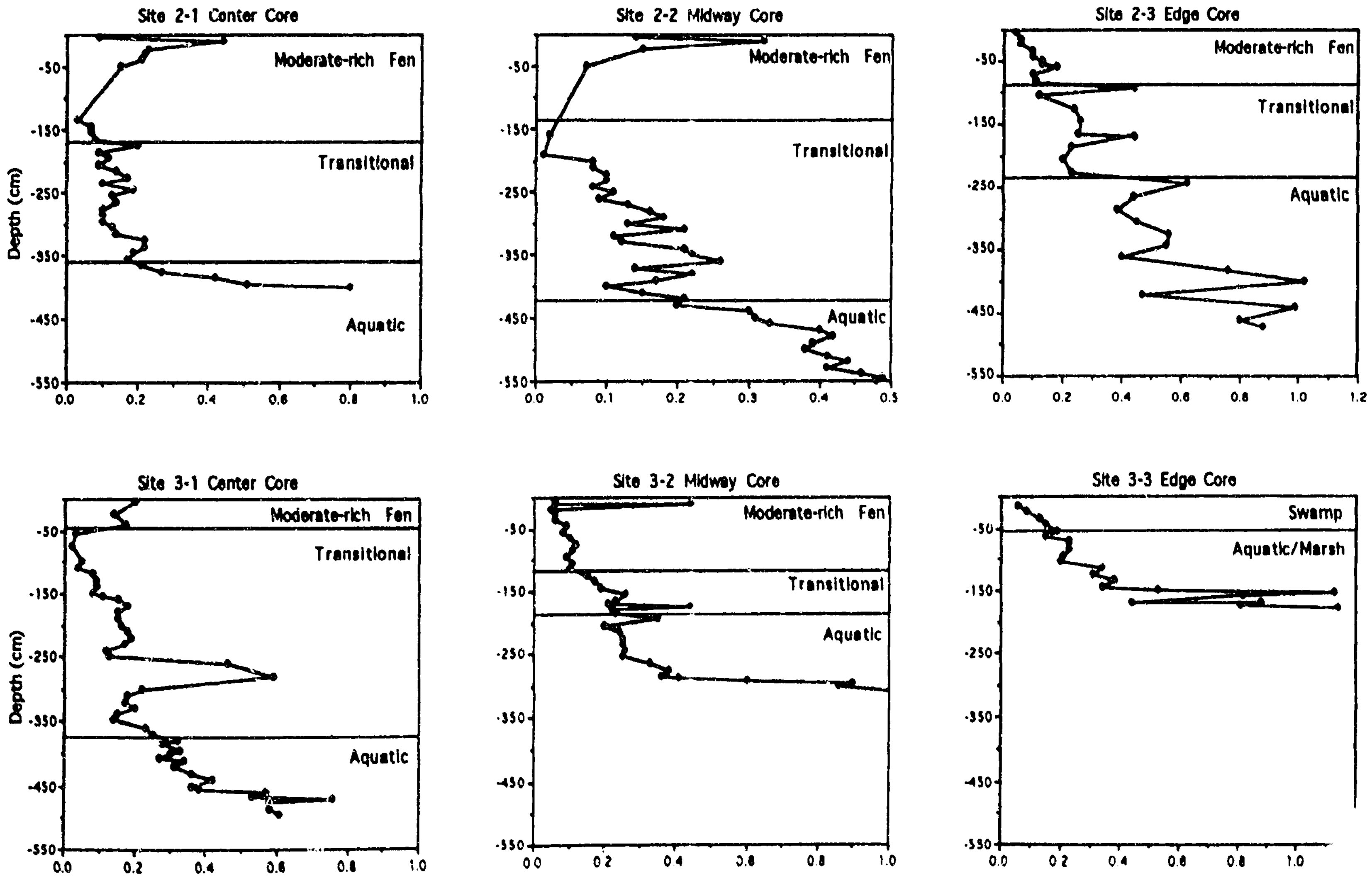


Figure 23
Physical Profiles
Bulk Density-Bogs g/cm^3

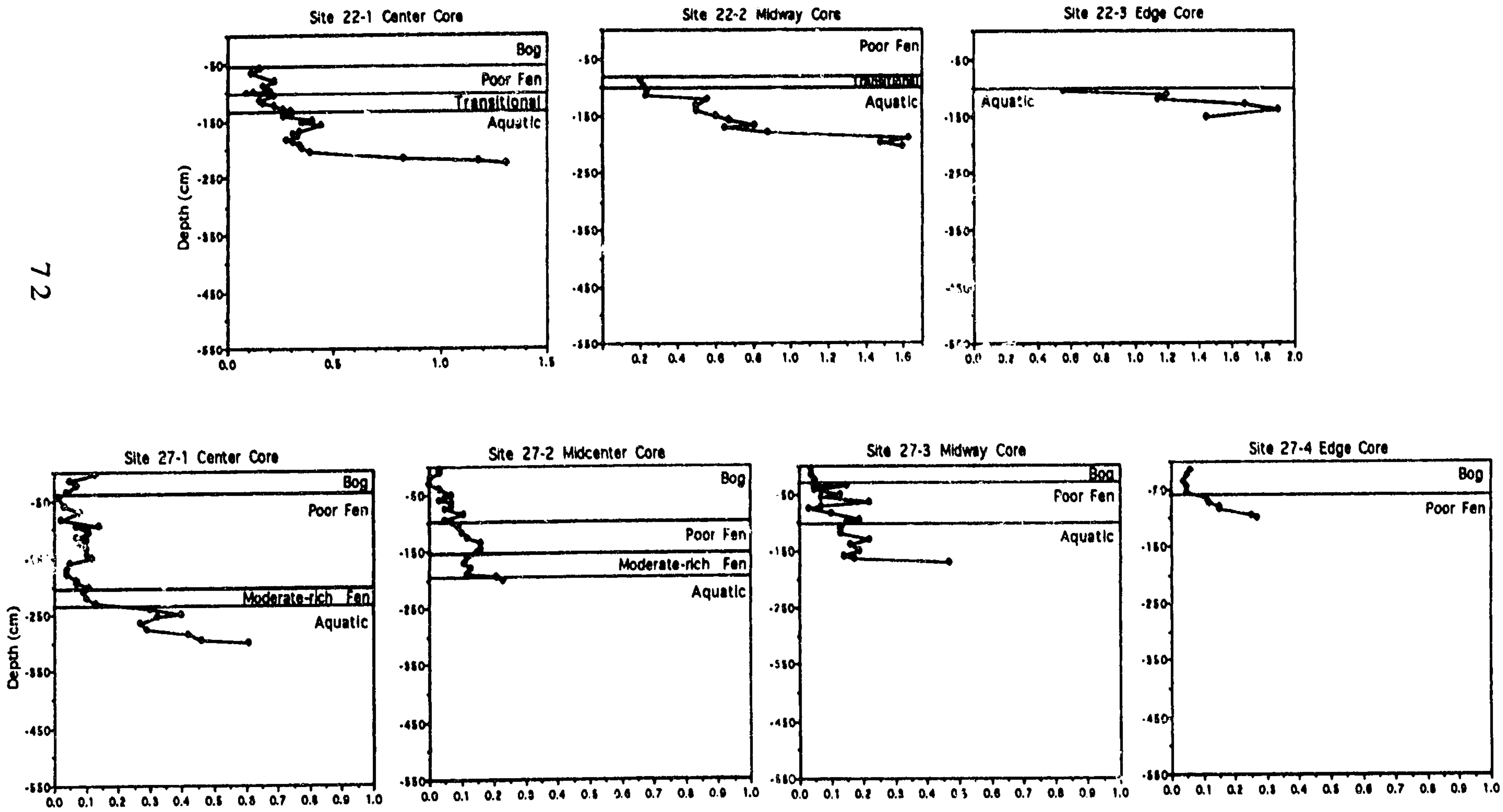
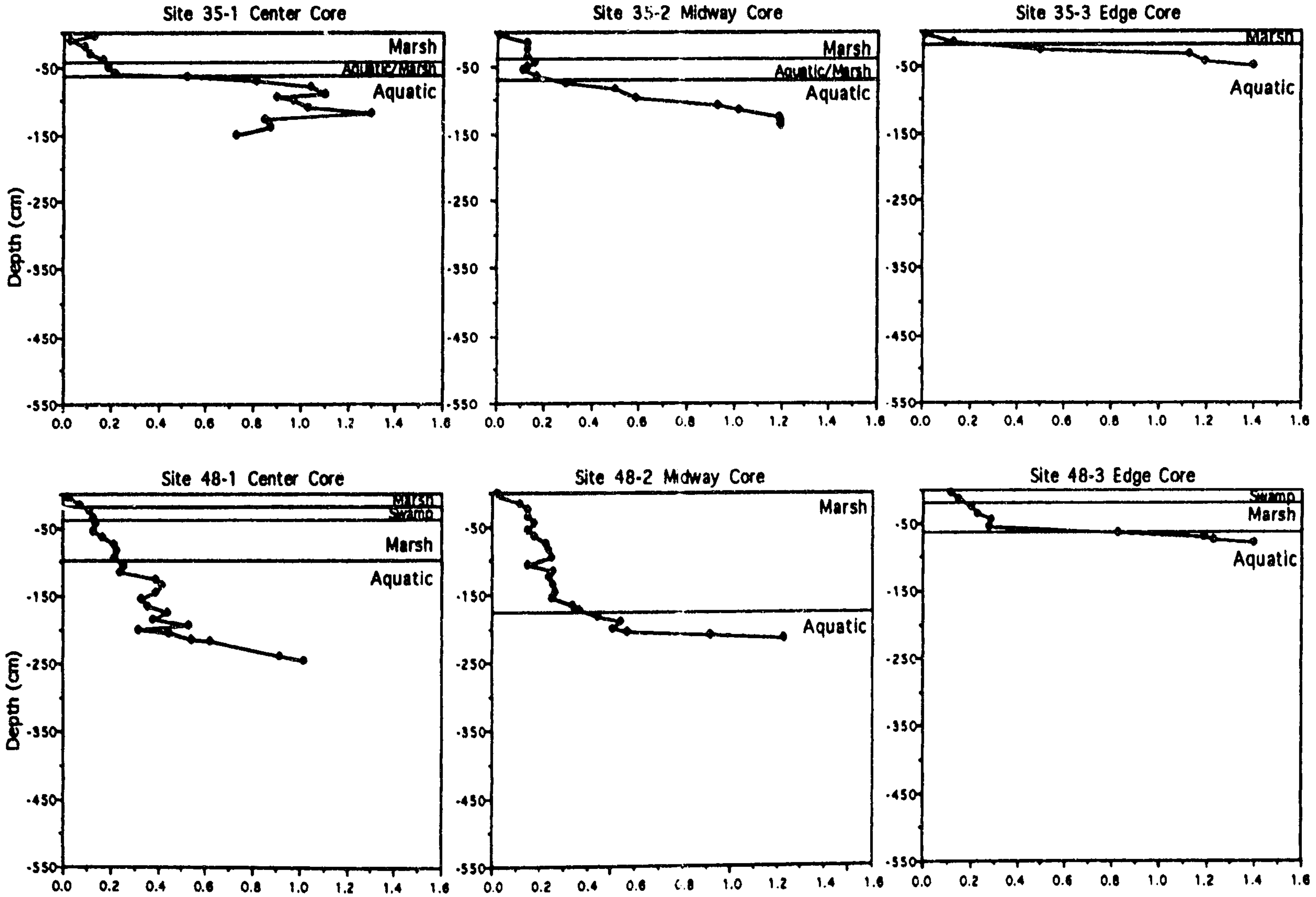


Figure 24
Physical Profiles
Bulk Density-Marsh/Swamps g/cm^3



the sediments were frozen at the time of sampling, and volumetric measurements could not be taken. Basal aquatic peats in the marshes and swamps tend to be denser than fen and bog basal peats (>0.3 g/cm^3). These profiles decline rapidly to bulk density values usually less than 0.2 g/cm^3. Bulk density values in the surface peats of marshes and swamps are lowest at the surface compared to bog and fens which can have denser peats at the mire surface.

Chemical Profiles

Calcium

In calcium and copper profiles, there is a visible difference between cores taken in the center of the wetland and cores taken from the edge. Profiles of cores taken from the center portions of fens, have high calcium concentrations in the aquatic sediments (1 x10^5-7 x 10^5 mg/Kg, Fig. 25). This does not occur in edge core 2-3, as calcium values are stable around 1 x10^5. At edge core 3-3 aquatic/marsh sediments contain 5 x10^5-3 x10^5 mg/Kg of calcium peaking to 35 x10^5 mg/Kg in the swamp sediments. In the central cores, calcium concentrations decline gradually through the deep section of transitional peats, and stabilize at about 1 x10^5 mg/Kg in the moderate-rich fen peats. Central bog cores from bog site 27, (Fig. 26) contain approximately 1 x10^5 mg/Kg of calcium in the basal aquatic peats which is the lowest calcium values found through the fen profiles. Calcium values reduce very slowly through these peat profiles to lows of approximately 3 x10^4 mg/Kg at the peat surface. Core 22-1 has a slightly different profile than the others. Basal

Figure 25
Chemical Profiles
Calcium-Fens mg/Kg

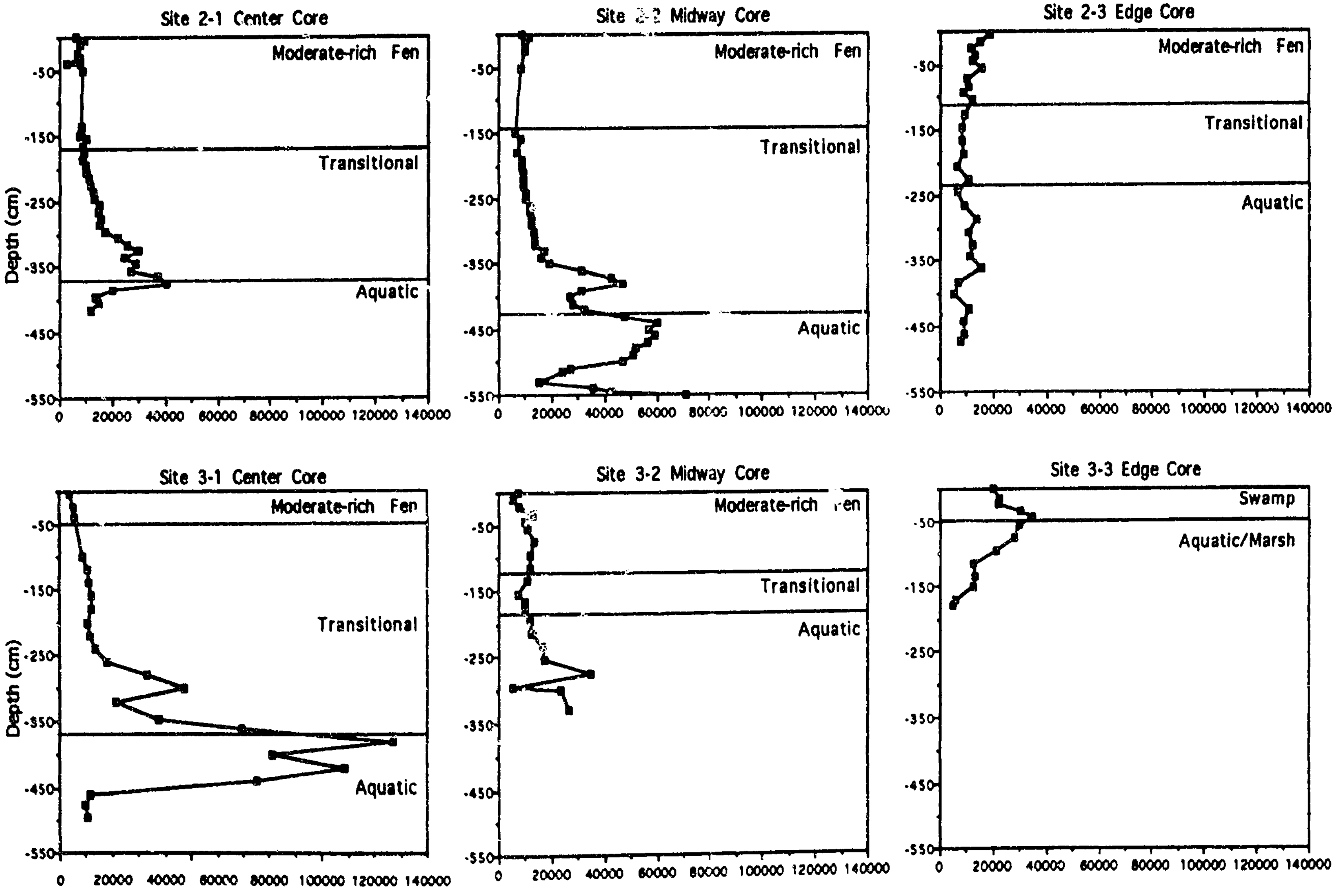
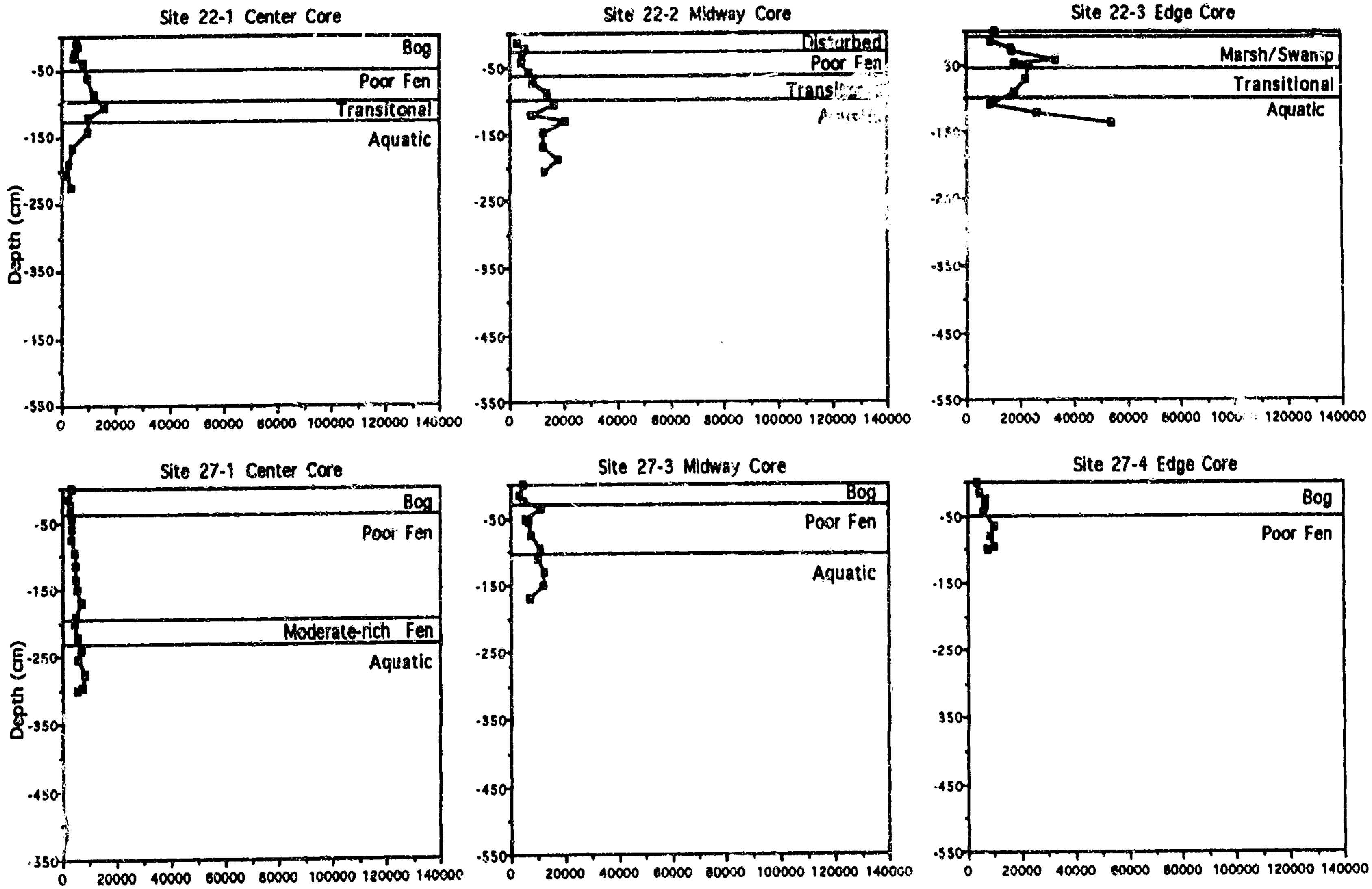


Figure [illegible]
Chemical Profiles
Calcium-Bogs mg/Kg



aquatic peats have extremely low calcium values (1.7 x 10^3-3.7 x 10^3 mg/Kg) which peak 15.6 x 10^3 mg/Kg before declining to 4.5 x 10^3 mg/Kg near the peat surface. Core 22-2 has basal calcium concentrations of 13-20 x 10^3 mg/Kg which decline to 3 x 10^3 mg/Kg at the peat surface. Calcium profiles from central cores at marsh site 35 (Fig. 27) are unique in that surface peats have much higher calcium concentrations than basal peats. Basal aquatic sediments contain 1 x10^4 mg/Kg of calcium, while peak calcium values of 35 x 10^3 mg/Kg occur 50 cm below the surface. The edge core (35-3) at this site has a highly variable calcium profile. At marsh site 48, calcium values are highest in the aquatic peats (70-150 x 10^3) and decline gradually to about 30 x 10^3 at the peat surface. At cores 48-1 and 48-3 calcium values rise at the surface to 50-70 x 10^3 mg/Kg. The calcium profile at swamp core 22-3 is distinctly more variable. Basal aquatic sediments contain calcium values of 5 x 10^4 mg/Kg, transitional aquatic/marsh/swamp peats average 2 x 10^4 mg/Kg, while surface sediments are somewhat reduced at 1 x 10^4 mg/Kg.

Copper

In the fens of Elk Island National Park, basal aquatic peats contain 3-14 mg/Kg of copper (Fig. 28). Profiles describe a gradual reduction in copper towards the peat surface, with some surface enrichment. Transitional aquatic/fen peats range from [illegible] mg/Kg, while surface peats can contain as high as 18 mg/Kg. Copper concentrations in bog site 27 (cores 27-1, 27-3) decrease abruptly from high levels of 18 mg/Kg in the aquatic basal peats to approximately 3 mg/Kg in the fen peat (Fig. 29). At core 27-4 poor

Figure 27
Chemical Profiles
Calcium-Marsh/Swamp mg/Kg

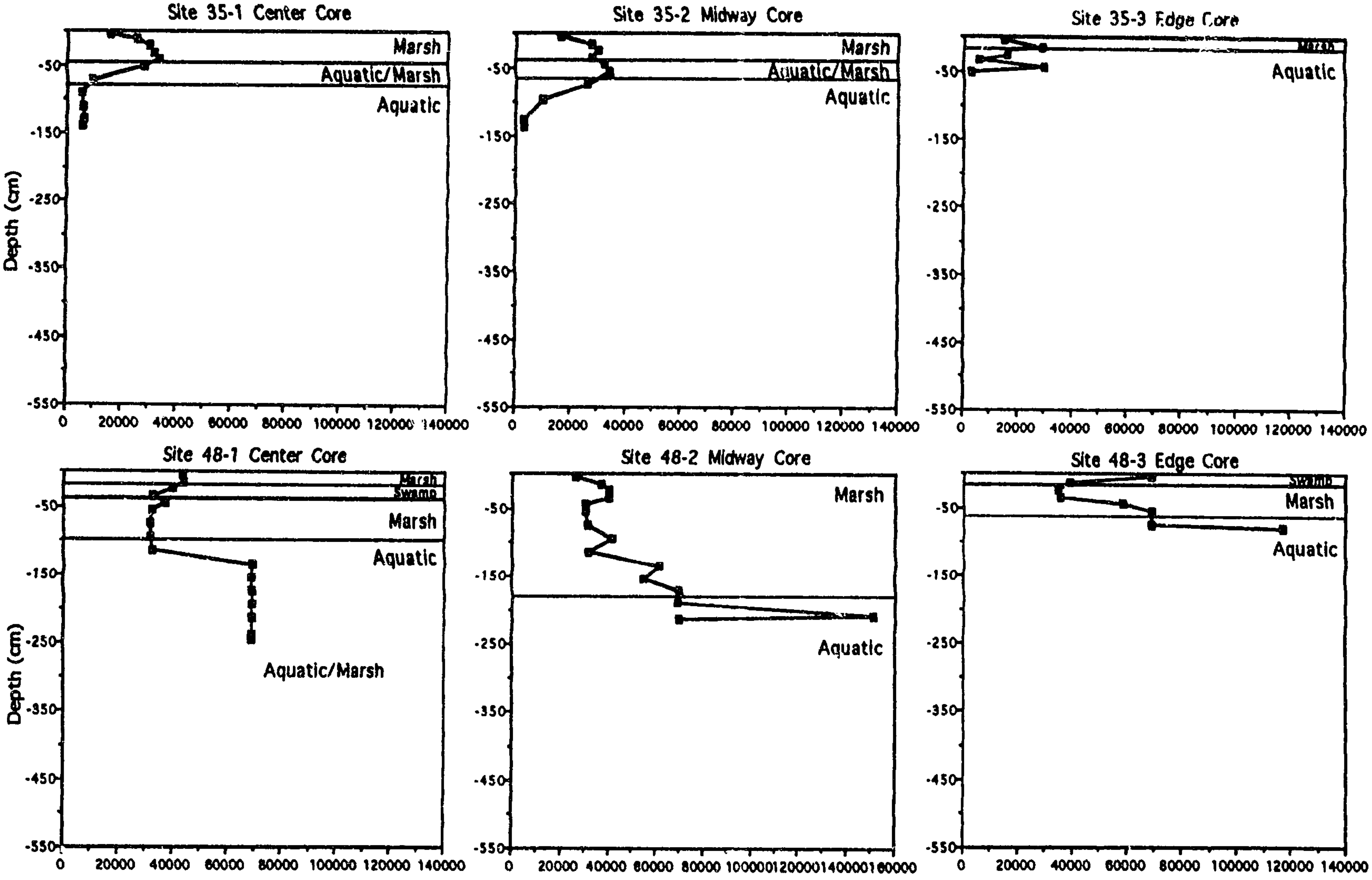


Figure 28
Chemical Profiles
Copper-Fens mg/Kg

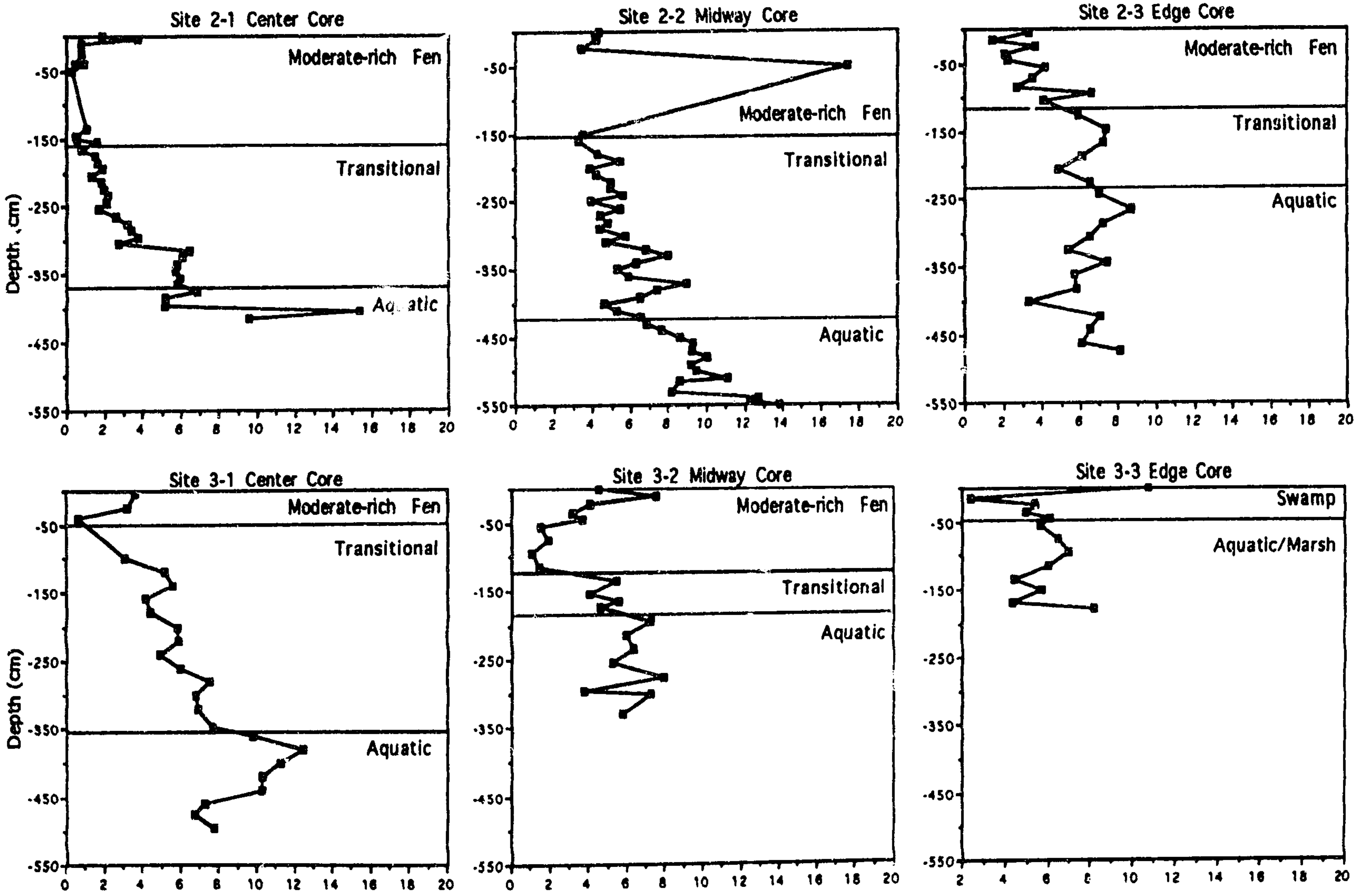
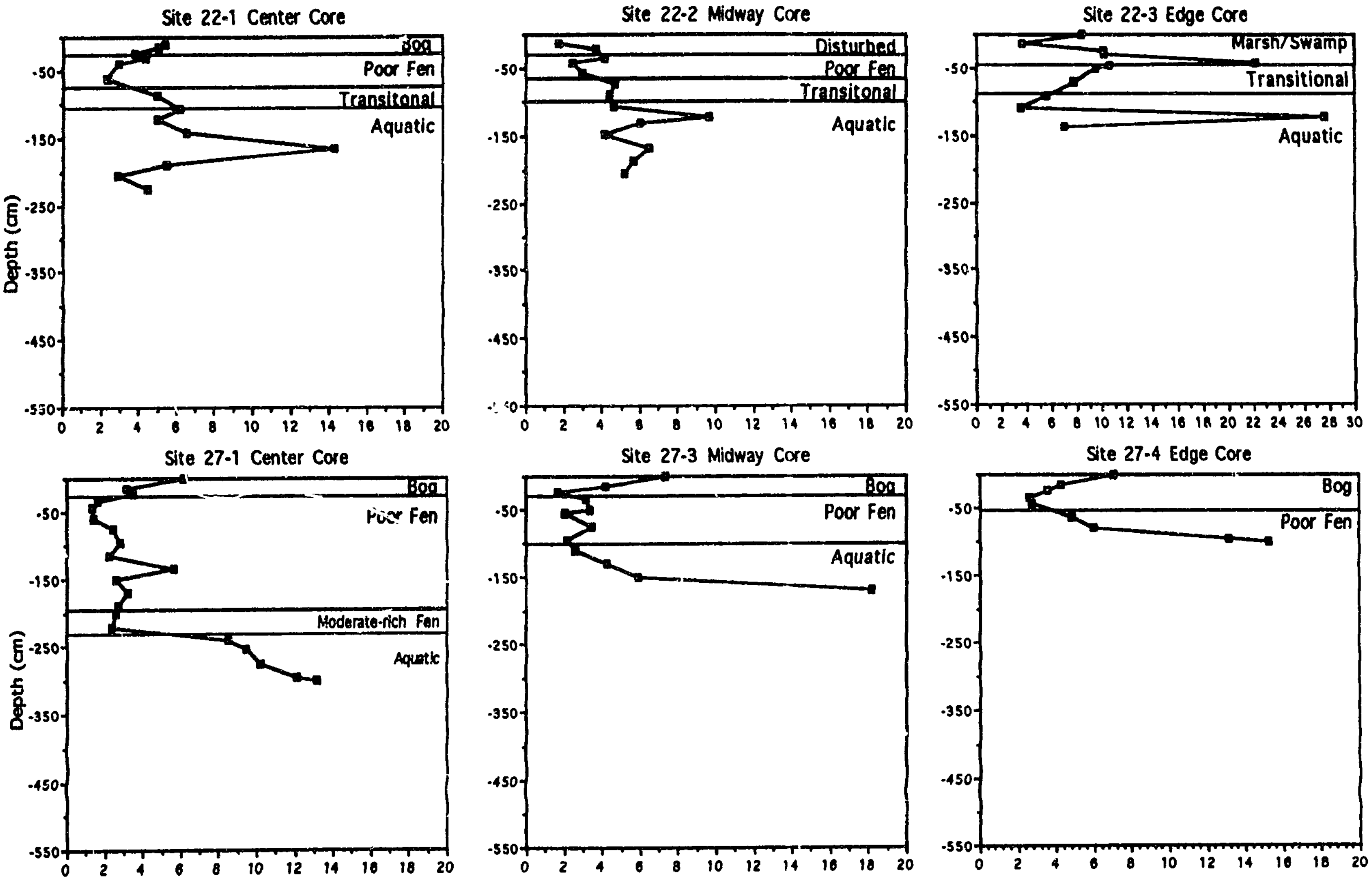


Figure 29
Chemical Profiles
Copper-Bogs mg/Kg



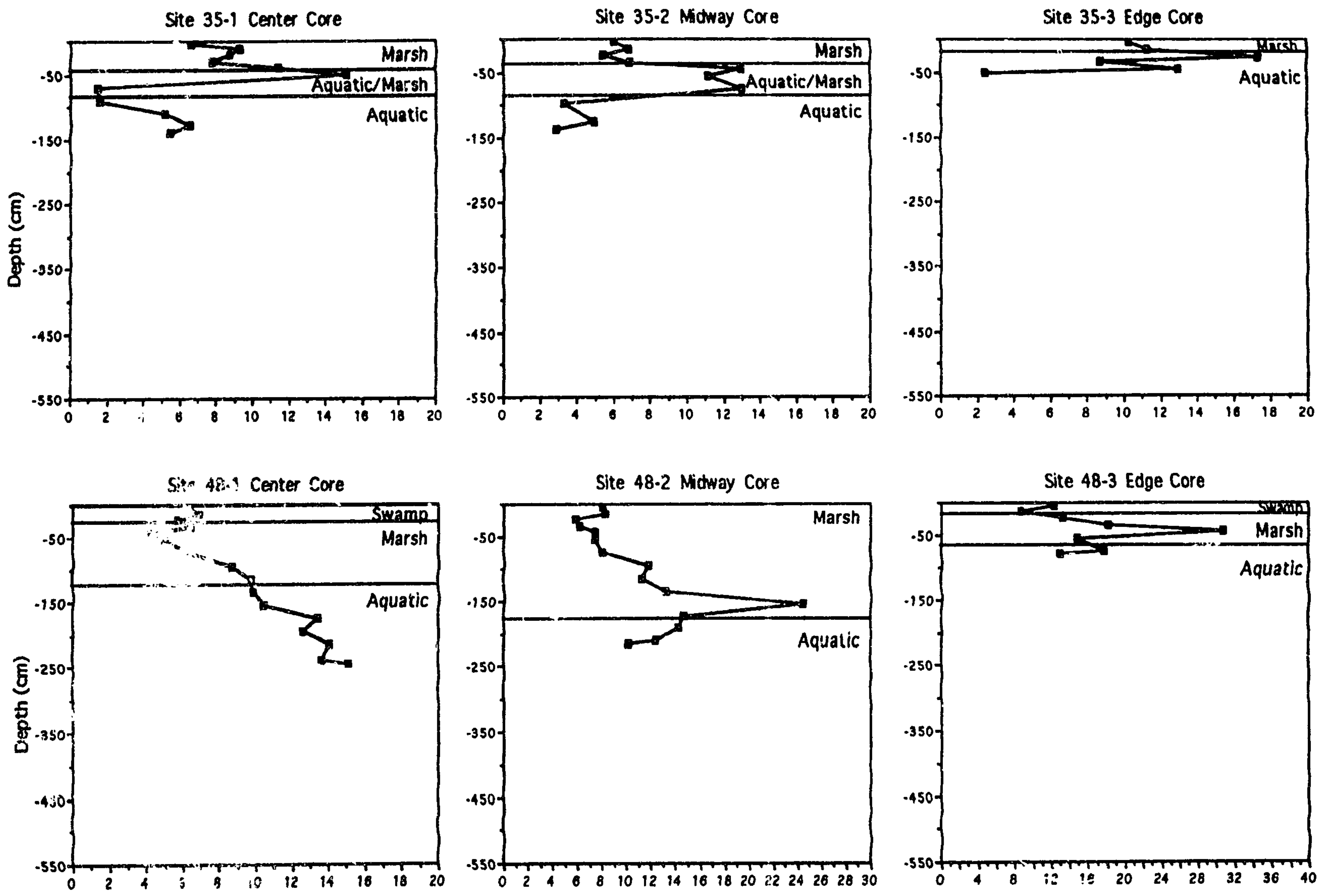
fen peats contain 5-15.8 mg/Kg. Surface enrichment of copper can be seen in all three profiles, with values ranging from 2-7 mg/Kg. At site 22 the central cores (core 22-1, 22-2), describe an initial flush of copper into the aquatic sediments peaking at 14 mg/Kg in core 22-1, followed by a reduction through the fen peats (average of 4 mg/Kg), and some surface enrichment (> 5 mg/Kg). Marsh and swamp cores have extremely variable copper profiles (Fig. 30). Initial copper flushes occur in the aquatic peats in cores 22-3, 35-1, 35-2, and 35-3, with peaks of 13-23 mg/Kg occurring in the lower marsh and aquatic/marsh sediments, and reductions in the upper marsh sediments. At cores 48-2 and 48-3, peak copper contents of 24 and 31 mg/Kg occur in the marsh peats above initial low (10-13 mg/Kg) copper values in [illegible]uatic peats. Core 48-1 describes a gradual reduction in copper from basal aquatic sediments containing 15 mg/Kg of copper to low values of 4 mg/Kg in marsh sediments 50 cm below the surface. The surface sediments at this core are slightly enriched at about 7 mg/Kg of copper.

DISCUSSION

Classification of Wetland Sites

Group 1 consisting of one site, represents a saline marsh as indicated by the presence of *Triglochin* and *Scirpus*, and by the high surface water values of corrected specific conductivity and sodium. Moss (1983) indicates that *Triglochin* is a perennial found in brackish marshes, while Stewart and Kantrud (1972) identifies *Triglochin maritima* as a species found in brackish to subsaline waters. Waters

Figure 30
Chemical Profiles
Copper-Marsh/Swamp mg/Kg



having specific conductivities higher than 500 µS are considered to be oligosaline by Cowardin *et al.* (1979), and slightly brackish by Stewart and Kantrud (1972). Millar ([illegible]) considers all water with specific conductivities less than 2,000 to be fresh. *Triglochin* dominated wetlands are classified as persistent emergent wetlands according to the U.S. classification system of Cowardin *et al.* (1979).

Group 2 consists of *Typha*-dominated deep marsh stands that are similar in species composition to *Scirpus-Typha* reed swamp vegetation identified by Lewis *et al.* (1928), and Moss (1953). A similar *Typha latifolia-Lemna minor* open fen vegetation was described by Jeglum (1972). *Typha*-dominated vegetation is found in emergent deep marshes (Millar 1976, Stewart and Kantrud 1972); slightly saline deep marshes (Walker and Coupland 1970); and shallow shore marshes by National Wetlands Working Group (1988). Cowardin *et al.* (1979) placed *Typha*-dominated vegetation into their palustrine persistent emergent wetlands group. This group, however is intermediate between emergent deep marsh and shallow marsh as defined by Shay and Shay (1986). The water chemistry of this group is considered to be slightly brackish by Stewart and Kantrud (1972), but fresh by Cowardin *et al.* (1979) standards.

Group 3 consists of *Carex aquatilis* and *Carex atherodes* dominated wetlands. They fit well into "meadow marshes" as defined by the National Wetlands Working Group (1988) and Walker and Coupland (1970). Similar vegetation was described as a broad leaved sedge fen by Jeglum (1972), and a low moor *Carex aquatilis* association by Lewis *et al.* (1928). *Carex atherodes* dominated vegetation is listed under shallow marsh communities by Millar

(1976), and Stewart and Kantrud (1972), while sedge dominated wetlands are classified as palustrine persistent emergent wetlands according to Cowardin *et al.* (1979). In Shay and Shay's (1986) classification this group is intermediate in composition between shallow marsh and wet meadow categories.

Group 4 consists of bryophyte dominated moderate-rich fens. This group bears some similarity to Glaser *et al.* (1990) spring fen channel vegetation with its mixture of *Carex lasiocarpa, Carex aquatilis,* and *Larix laricina*; Jeglum's (1972) narrow-leaved sedge fen category; and Vitt and Chee's (1990) moderate-rich fen species of Stand Group 2. Moss (1953) considered this vegetation to be a marsh-bog transition and Lewis *et al.* (1928) a low moor caricetum. According to the U.S. classification system of Cowardin *et al.* (1979), this wetland community is a palustrine persistent emergent wetland, while the Canadian System of Classification considers these to be sedge-grass type basin fens (National Wetlands Working Group 1988).

Group 5 consists of shallow marsh stands that appear to have developed in a more stable environment than Group 3 as they contain a larger number of bryophyte species and *Carex lasiocarpa*, a species more common in fens. This group is considered to be a meadow marsh by the National Wetlands Working Group (1988), and Walker and Coupland (1970); a broad leaved sedge fen by Jeglum (1972); fen emergent vegetation by Stewart and Kantrud (1972); a low moor *Carex aquatilis* association by Lewis *et al.* (1928); a shallow marsh by Millar (1976); and a shallow marsh/wet meadow intermediate by Shay and Shay (1986). This group has some affinities with widespread hummock species described by Vitt and Chee (1990) for fens in Alberta.

Group 6 consists of *Salix* dominated swamps similar to either the low shrub or tall shrub fens of Jeglum (1972); willow swamps of Moss (1953); *Salix-Calamagrostis canadensis* association of Lewis *et al.* (1928); and shoreline shrub thickets of Ovenden and Brassard (1989). Millar (1976) considered *Salix* dominated vegetation to be parkland versions of a wet meadow. In the U.S., this vegetation would be classified as a scrub-shrub wetland (Cowardin *et al.* 1979).

Group 7 consists of alder dominated swamps, that resemble tall shrub thickets found in the Yukon described by Ovenden and Brassard (1989); alder-willow swamps described in Alberta by Moss (1953); and tall shrub fens identified in central Saskatchewan by Jeglum (1972). This group would also be considered as a parkland wet meadow wetland by Millar (1976).

Group 8 consists of *Sphagnum* bogs that have open canopies due to a recent fire. They are similar to the *Picea mariana-Ledum groenlandicum-Sphagnum magellanicum* association described in Alberta by Vitt *et al.* (1975), and mire expanse communities found in eastern North America by Gauthier (1988). Similar vegetation associations are found in *Sphagnum* bogs described by Moss (1953), and open bogs of Jeglum (1972). This type of wetland is classified as a basin bog in the Canadian system (National Wetlands Working Group 1988), and as a moss-lichen wetland in the American system (Cowardin *et al.* 1979).

Group 9 consists of *Sphagnum* dominated bogs that have dense *Picea mariana* canopies. Jeglum (1972) accurately described this association as "wooded bogs". This group appears to be a dry version of the *Picea mariana-Sphagnum* association described in Alberta by Moss (1953). Lewis *et al.* (1928) considered this vegetation type to be the mature hydrarch climax stage for the Edmonton area. In the American wetland classification system this association is equivalent to needle-leaved evergreen and scrub-shrub wetlands (Cowardin *et al.* 1979).

Group 10 consists of *Sphagnum* dominated poor fens with high *Larix* cover. This group conforms most closely to Jeglum's (1972) tamarack swamp category, and Sims *et al.* (1982) *Sphagnum*-rich treed fens in James Bay, Ontario. Cowardin's *et al.* (1979) American classification system identifies this wetland as a needle-leaved deciduous forest wetland.

Group 11 consists of poor fen stands that have significant alder and birch cover. They resemble *Sphagnum*-rich treed fens described by Sims *et al.* (1982), and *Carex aquatilis-Chamaedaphne-Sphagnum* meadows described by Ovenden and Brassard (1989) in the Yukon. According to Cowardin *et al.* (1979) this association is a moss wetland.

Group 12 consists of *Picea glauca-Picea mariana-Larix laricina* swamp associations. This association is classified as a needle-leaved evergreen wetland in the American system of wetland classification (Cowardin et al. 1979). This vegetation type has not been described previously in western Canada, but similar vegetation associations are present in the peat margin swamps of eastern temperate Canada (National Wetland Working Group 1988).

Group 13 consists of *Sphagnum* dominated poor fens with some *Betula, Picea, Larix,* and *Salix* cover. They are most closely related to

Ledum moors, an early *Sphagnum-Andromeda* association described near Nestow, Alberta by Lewis *et al.* (1928). In the U.S., this association would be considered a moss wetland (Cowardin *et al.* 1979).

Correlation of Vegetation to Water Chemistry and Environmental Factors

Data reported from other sources indicate that marshes are typically circumneutral to alkaline in water chemistry. Hydrogen ion activity (pH), specific conductivity, calcium, magnesium, and sodium concentrations can be variable in marshes, ranging from 5.6-8.2, 83-500 µS, 2-72 mg/l Ca, 1-12 mg/l Mg, and 3-50 mg/l Na (Table 8). Ionic concentrations found in the marshes at Elk Island National Park are consistent with the range of values reported in Table 8. Calcium, magnesium, sodium, corrected specific conductivity, and pH levels in swamps reported from other studies indicate that swamps are also generally circumneutral to alkaline and equally as variable in their water chemistry (Table 8). Ionic concentrations in the swamps at Elk Island are similar to data presented in Table 8. Moderate-rich fens at Elk Island have lower pH, specific conductivity and cation concentrations than macrotrophic and rich fens found elsewhere in Alberta (Table 8). They are comparable to moderate-rich fens, mesotrophic fens, water tracks at Mariana Lakes, graminoid fens, and low shrub fens in pH and corrected specific conductivity. Dust from agricultural soils may be contributing to some calcium enrichment of

Table 8
Wetland Surface Water Chemistry Data - Published Reports

Type	Description	Reference	pH	Cond µS	Ca mg/l	Mg mg/l	Na mg/l	TKN µg/l	NO3 µg/l	NH4 µg/l	TP µg/l	Notes **
Marsh	Bulrush	S. Campeau et al. unpublished	8.2	500				1383			21	
	Shore Marsh	National Wet Wor Gr 1988	7	95	16							
	Meadow marsh	National Wet Wor Gr 1988	6.8	97	15							
	Marsh/Fen	Vitt et al. 1992	6.7-6.8	180-186	23	8	4-6		4-9	6-7	40-77	
	Thelypteris-reed	Wassen et al. 1989	6.4	440	72	1	51		242	265		sample depth=0.5m
	Floating Marsh	National Wet Wor Gr 1988	5.6	63	9							
	Carex Aquatilis	Cowardin et al. 1979	>5		2							
Swamp	Conifer	Schwintzer 1981	7.4		38	11						
	Conifer	Schwintzer 1981	7.2		44	13						
	Conifer	Schwintzer 1981	7.2		50	12						
	Conifer	Schwintzer 1981	7		28	11						
	Mesotrophic Hard.	Zoltai and Johnson 1987	6.1	379	60	19	5				210	
	Alnus	Wassen et al. 1989	6	345	20	0.5	37		235	6000		
	Mesotrophic Conif.	Zoltai and Johnson 1987	5.7	192	23	9	5				140	
	Mesotro Thickwood	Zoltai and Johnson 1987	5.5	182	20	9	7				580	
	Coniferous	National Wet Wor Gr 1988	4.7		8	4					100	
Fen	Rich	Vitt and Chee 1990	7.1-7.3	212	62	15	7	1500**	25	42	40	ORG-N
	Rich	Rochèfort 1987	7.3-8	436-619	43-85	21-27	23-33		5-42	3-77		
	Macrotrophic	Zoltai and Johnson 1987	6.9	436	64	17					130	
	Moderate-rich	Vitt and Chee 1990	6.2-6.7	68	21	5	6	2234**	7	53	80	ORG-N
	Graminoid	Sims et al. 1982	6.6	140**	22	4	9	1100			200	µmho
	Forested Rich	Vitt et al. 1992	6.1-6.3	82-90	11-12	5	2-3		4-8	15	250-406	
	Gramin. RichTreed	Sims et al. 1982	6.1	91**	17	3	6	1400			300	µmho
	Low Shrub	Sims et al. 1982	6	200**	17	5	20	1700			400	µmho
	Open Rich	Vitt et al. 1992	5.8	79	10	4-5	1-2		5-7	9	122-412	
	Water Tracks	Nicholson 1987	5.1-6.3	148	10	2	1.6	1079	7	11	0	
	Mesotrophic	Zoltai and Johnson 1987	6	245	29	11				5	130	
	Houghton Lake	Richardson et al. 1978	5.1		19	4			39	728	20	
	Poor Fen	Vitt et al. 1992	5.4	48-60	6-8	3-4	2		5-10	13-15	96-580	
	Spheg. Rich Treed	Sims et al. 1982	5.4	52**	7	1	4	1200			200	µmho
	Poor Fen	Vitt and Chee 1990	4.5-4.8	15-28	2	0.4	0.4	965	8	22	10-20	ORG-N
	Oligotrophic	Zoltai and Johnson 1987	4.7	52	1	0.3	5				190	
	Open Fen	Nicholson 1987	3.5-5.4	37.7	3	0.8	0.9	1385	10	23	30	
	Big Run	Weider R.K. 1905	4		0.9	0.2	0.2		139	166		
	Lakkasuo Mire	Starr and Laine 1988	4.5-5.4		2-3			350-720**	2-4	30-90		ORG-N
	Coastal, B.C.	Vitt et al. 1990	4.4-6.6		0.4-0.9	0.3-0.5	1-4					
Bog	North Plateau	National Wet Wor Gr 1988	4.7		2	2					200	
	Oligotrophic Treed	National Wet Wor Gr 1988	4.5	62	2	0.8	2				170	
	Basin B og	National Wet Wor Gr 1988	4.4		4	2					200	
	Bog	Vitt et al. 1992	3.9	36-39	3-4	0-1	1-2		8-11	17-18	42-140	
	Mariana Lakes	Nicholson 1987	3.6-4.5	11	2	0.5	0.8	1417	9	26	260	
	High Moor	Yefimov and Yefimova 1973	3.6-5.2		2	0.5	0.8		545	140		
	Lakkasuo Mire	Starr and Laine 1988	3.6-3.9		1-2			650-870**	1-3	20-13[illegible]		ORG-N
	Coastal, B.C.	Vitt et al. 1990	4.1-4.8		<0.1	0.2-1.6	0.5-14					

wetlands at Elk Island National Park (Gorham *et al.* 1984) compared to peatlands located in more remote areas of North America. Calcium concentrations in the moderate-rich fens average 33 mg/l as compared to a range of 3-22 mg/l found elsewhere (Table 8). The poor fens at Elk Island have lower pH values compared to similar wetlands published in the literature (Table 8), however specific conductivity is higher. Calcium concentrations are variable but can be high (7 mg/l, Table 2), as well as magnesium (2 mg/l) and sodium (4 mg/l). This may be due to additional inputs from windblown soil of the largely agricultural surrounding area. Specific conductivity and pH values in bogs at EINP are most similar to bogs at Mariana Lakes, Alberta, and high moor bogs from the Soviet Union (Yefimov and Yefimova 1973). Calcium, magnesium, and sodium concentrations of these bogs are also slightly enriched compared to other reported sites (Table 8).

Organic nitrogen values vary in Elk Island marsh wetlands from 2013-6384 µg/l. This is predominantly soluble particulate N, which is exuded from vegetation or is a product of decomposition (Wetzel 1983). These values are much higher than TKN-N concentrations (1383 µg/l) found in a bullrush marsh in Manitoba (Campeau *et al.* unpublished). High organic N in the saline marsh at Elk Island maybe due to high rates of decomposition and concentration of the decompositional products by evapotranspiration. Bullrush marshes are much closer in structure and chemistry to open water systems than closed stand *Carex* dominated marshes studied in Elk Island. Hypereutrophic lakes normally have > 1200 µg/l organic N in the epilimnion, and anaerobic hypolimnions can have as high as 10 mg/l (10,000 µg/l) organic nitrogen (Wetzel 1983).

Ammonium and nitrate concentrations in swamps at EINP are comparable to those reported in Table 8. As combined inorganic nitrogen, these values range from 30-153 µg/l; less than levels commonly found in ultra oligotrophic lakes (Wetzel 1983). This indicates that the wetland plants are either rapidly assimilating or adsorbing any available inorganic nitrogen in these wetlands, or very little organic N is being mineralized to ammonium. Fens are also extremely low in nitrate and ammonium (Table 8). Bogs often contain much higher ammonium levels than fens (Table 8). Nitrification of ammonium is inhibited by dissolved organic compounds, especially tannins, acidic conditions (Wetzel 1983), and phosphorus deficiency (Damman 1988). Any or all of these could contribute to high ammonium levels in bogs. The moisture regime, as influenced by the depth of the water table will influence the amount of N mineralization and ammonium which accumulates (Richardson *et al.* 1978). Loss of ammonium through denitrification is often inhibited or occurs at very low levels in wetlands (Hemond 1983, Urban and Bayley 1988). Inhibited denitrification plus rapid uptake by plants (Urban and Eisenreich 1988, Urban and Bayley 1988) results in undetectable or very low levels of NO_3 in bogs (Gorham *et al.* 1984).

Total phosphorus is a measure of soluble inorganic and organic P, and particulate P. The majority of total phosphorus is in an organic phase as particulate P (Wetzel 1983), and is therefore a product of decomposition. Hypereutrophic lakes contain greater than 100 µg/l of total phosphorus in the surface waters (Wetzel 1983). Surface water in the marshes at EINP have total phosphorus concentrations ranging from 73-250 µg/l, which agrees with data acquired by Vitt *et. al* (1992). Published data (Table 8) indicates that swamps can contain anywhere from 100-580 µg/l TP in their surface waters, while values at EINP range from 221-3155 µg/l. Total phosphorus in fens has been reported ranging from undetectable to 466 µg/l (Table 8). Data collected from the fens at EINP generally agree with these values. Low phosphorus measurements in fen Groups 4 and 10 are related to low amounts of organic N, suggesting decomposition is limited at these sites. Both bog groups had higher total phosphorus concentrations in interstitial waters than reported from other authors (Table 8). Nitrogen and phosphorus mineralization was found by Verhoeven *et al.* (1990) to be higher in ombrotrophic bogs with a *Sphagnum* cover than in minerotrophic fens. Low water tables may be contributing to faster decomposition in the bogs at Elk Island.

The distribution of wetland species along pH and ionic gradients has been well documented for peatlands (Sjörs 1950, 1952, Vitt *et al.* 1975, Vitt and Slack 1975, Karlin and Bliss 1984, Glaser 1983, Vitt and Bayley 1984, Malmer 1986, Gignac 1987, Starr and Laine 1988, Chee and Vitt 1989, Wassen *et al.* 1989, Gignac et al. 1991(a), Gignac *et al.* 1991(b), Glaser *et al.* 1990, Nicholson and Vitt 1990, Renato 1990, Vitt *et al.* 1990), and lakes (Jackson and Charles 1988, Arts 1990). Species distribution is a result of habitat requirements of which bryophytes are known to be particularly sensitive (Vitt and Slack 1984, Andrus 1986, Janssens and Glaser 1986) and the ability of plants to modify their surrounding environment (Andrus 1986, Gorham *et al.* 1984, Glime *et al.* 1982, Kangas 1990). Examples of environmental modification by plants are acidification (Gorham *et al.* 1987), organic matter build up, and physical resistance to water movement (Vitt and Kuhry 1992).

Wetland species will respond to environmental gradients by producing wetland communities that reflect regional climate, local hydrology, water chemistry, basin morphology, and disturbance. The strongest gradient controlling species distribution in Elk Island National Park appears to be an ionic gradient reflected in cation concentrations, pH, and corrected specific conductivity. Superimposed on this gradient is a nutrient gradient influenced by variations in nitrogen and phosphorus levels. Ionic gradients are controlled most strongly by water source, flow rates, and precipitation, while nutrient levels are controlled by chemical cycles within the peatland. Moisture conditions and redox potentials also play a significant role in regulating available nutrients in wetlands.

The ionic gradient in wetlands at Elk Island National Park is largely driven by the water source (ombrotrophic vs. minerotrophic) and fluctuating water tables. Low elevational shore marshes are closely tied to adjacent aquatic environments with the highest number of inlet and outlet streams, and are subject to periodic drawdown and flooding. The maintenance of species diversity and deep emergent vegetation in these sites is often dependent upon cycles of drought and flooding (Keddy and Reznicek 1986, Mallik and Wein 1986, Greening and Gerritsen 1987, Welling *et al.* 1988(a), 1988(b), Wilcox and Meeker 1991). High specific conductivities approaching those of brackish waters is indicative of semi-permanence (Stewart and Kantrud 1972) and is characteristic of the marshes at Elk Island National Park. Swamps are formed at intermediate elevations usually at the outermost fringe of the wetlands at Elk Island National Park. Cation sources for these wetlands include overland flow and underlying soils. Groundwater seepage is considered to be a major factor for swamp development, but data presented here suggest that one group of swamps at Elk Island is a product of stagnant water combined with either a shallow water table or periodic drawdown. Fens form at intermediate elevations where shallow water tables intersect the soil surface along low sloping gradients. Surface and groundwater slowly seeps across these peatlands. Basin fens receive intermediate overland flow in terms of the number of inlet and outlet streams. They usually are formed as floating mats that extend out from the basin edge into open waters. Mineral additions to the floating mats are minimized by the ability of the mat to float with rising water levels. Bogs mostly form at Elk Island National Park at the highest elevations in isolated perched depressional basins. Overland flow is minimal and water movement is restricted to one or two inlet and outlet streams.

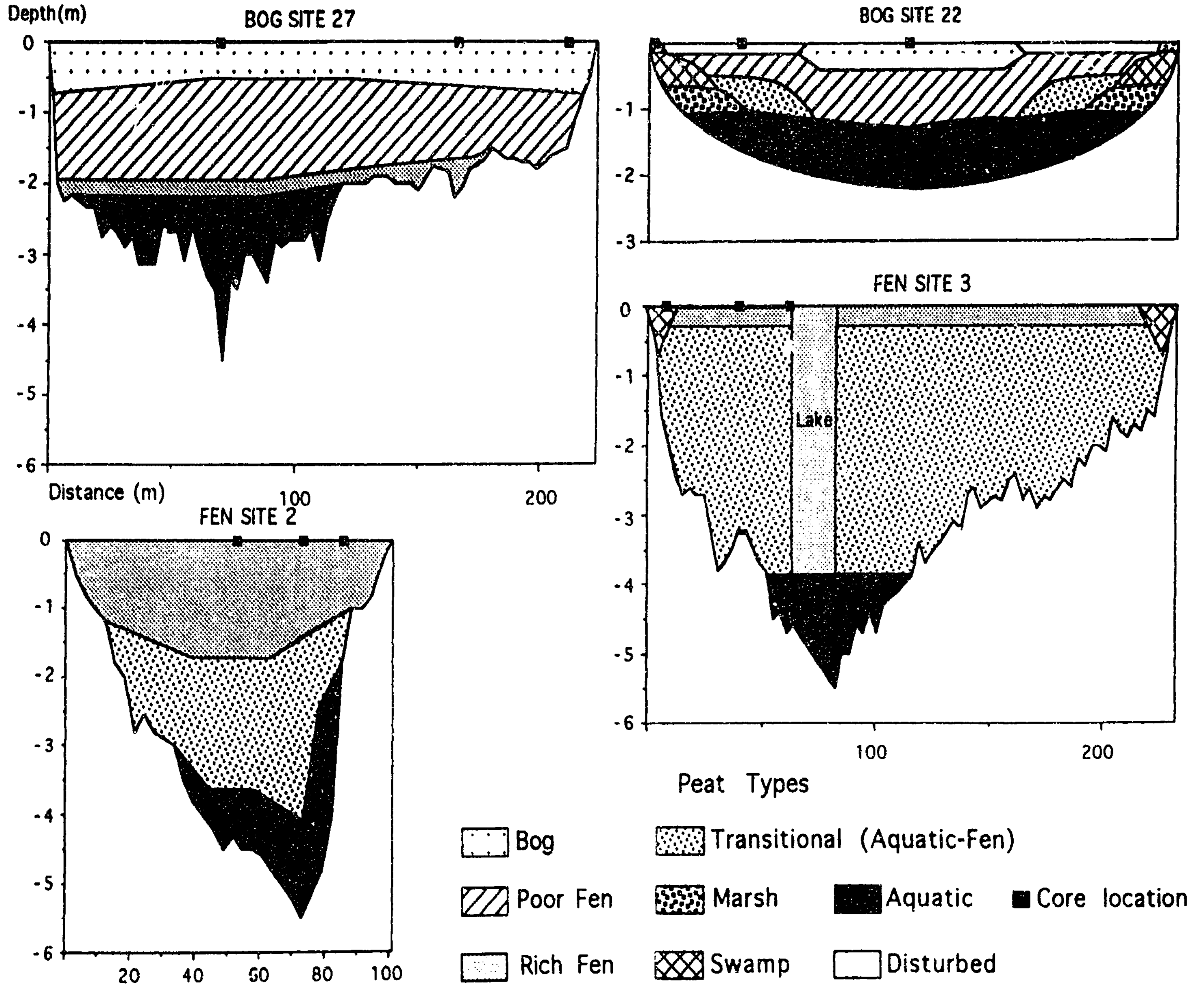
Peatland Development

Site 2

Three phases can be recognized from the profiles of all three cores at site 2 (Fig. 31). The first phase is an aquatic phase dominated by aquatic plant and seed remains. *Carex* and bryophytes can be found in this phase in low abundance in all three cores. The presence of

Figure 31

ELK ISLAND NATIONAL PARK SUMMARY PEATLAND DEVELOPMENTAL PROFILES



mineral grains and a high percentage of detritus indicates that mixing and a high rate of decomposition occurred at the time of deposition, however, a permanent water body is suggested by the presence of *Amnicola limosa* and *Menetus cooperi* shells (Clarke 1981). The aquatic phase is followed by a transitional phase that contains both aquatic and semi-terrestrial plants. The extant phase is a moderate-rich fen community. Bryophyte species are predominant along with *Carex, Betula* and herbaceous material. This site has progressed from a pond-marsh where a shallow open body of water containing floating and emergent aquatic plants has slowly changed into a bryophyte/*Carex* dominated moderate-rich fen.

Site 3

The deeper portion of this basin was first occupied exclusively by aquatic plants (Fig. 31). A permanent water body is suggested by the presence of *Valvata sincera helicoidea*, a gill breathing snail (Clarke 1981). Gradually, a floating mat developed producing a large section of transitional peat. At present this floating mat is a moderate-rich fen comprised of bryophytes, sedges, and shrubs. The outer edge of this peatland flooded much later (Table 3) and initial sediments were comprised of both aquatic and semi-terrestrial plants. Close proximity to upland vegetation is indicated by the presence of woody elements, *Betula*, and *Alnus* nutlets in the basal peats. A high percentage of woody elements in the upper section of the edge profile suggests that a woody swamp developed following the earlier aquatic phase.

Site 22

Mineral soil mixed frequently with the basal aquatic sediments at site 22, and snail shells indicative of permanent water bodies are lacking (Fig. 31). *Sphagnum* fossils are present in low amounts at the base indicating that it was present in some quantity nearby. A transitional community occurred for some time, combining aquatic species with *Carex* and minor percentages of *Sphagnum* and *Drepanocladus*. In the center of the peatland, the aquatic community was quickly replaced by a *Sphagnum* dominated poor fen. This was followed by a *Sphagnum* dominated bog community, devoid of *Carex*, herbs and brown moss species. The midway core does not develop this bog phase, and the poor fen stage lasts until a few centimeters below the peat surface. Disturbance by beavers has reflooded this site altering the top few centimeters of this core to a herbaceous dominated community. Basal sediments at the edge of this site are aquatic indicating that this basin expanded in size due to increased water levels. These sediments change into a transitional assemblage consisting of aquatic species, Gramineae, *Betula*, and *Alnus*. The next phase has high percentages of woody elements, *Betula* and *Alnus* indicating that a marshy swamp developed. Surface peats show a reduction in woody elements, *Betula* and *Alnus*, and a dramatic increase in herbaceous material and *Carex* suggesting the flooding has created wetter conditions that killed the shrubs and trees previously surrounding the peatland. The profiles at this site suggest that this peatland was developing into a *Sphagnum* dominated bog, but was arrested at the margins by disturbance due to flooding. Lagg development had progressed from an aquatic community to a marshy swamp community before disturbance occurred.

Site 27

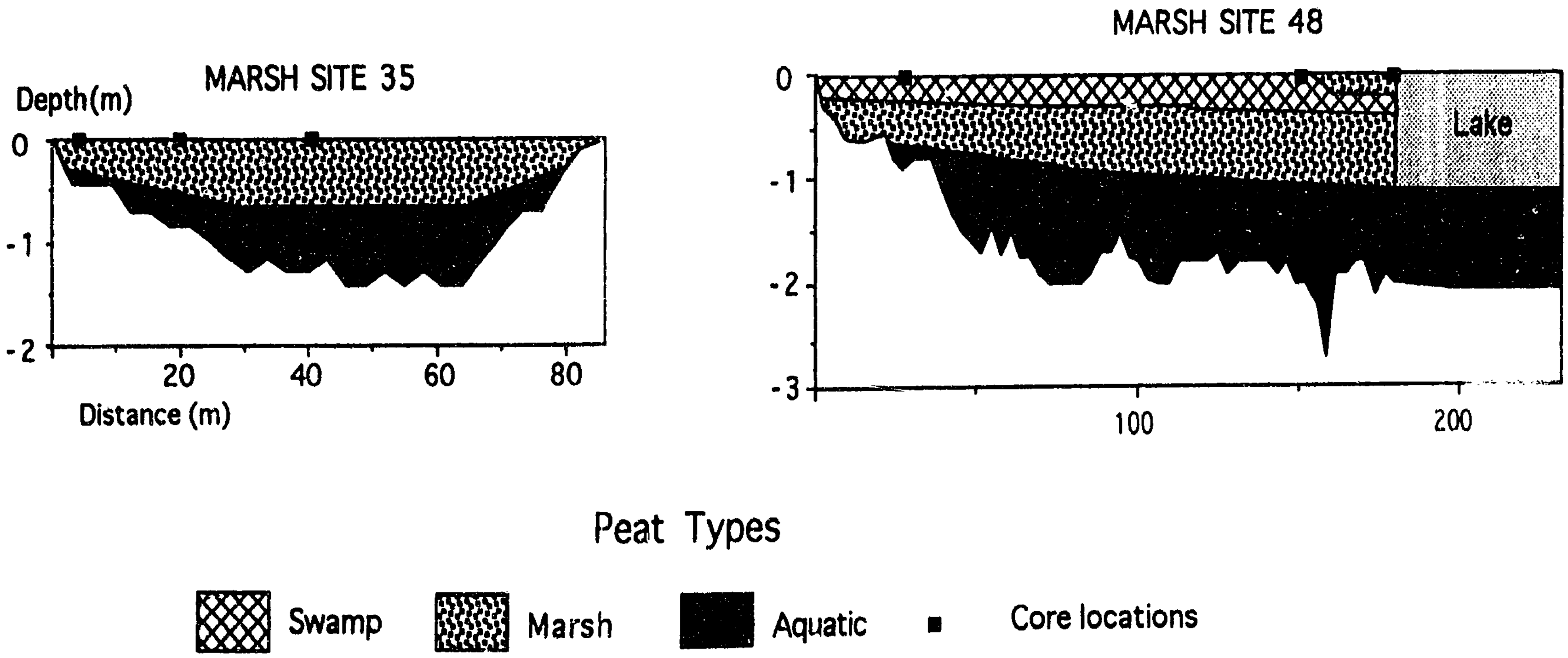
Four phases can be seen in the profile of site 27 (Fig. 31). The first stage is predominantly aquatic but there is some evidence of terrestrial plants. Snail shells indicative of permanent water bodies are absent from the basal sediments at this site (Clarke 1981). A bryophyte dominated moderate-rich fen community quickly replaced the aquatic phase, followed by a *Sphagnum* dominated poor fen. Succession has terminated with a bog community dominated by a limited number of *Sphagnum* species including *Sphagnum fuscum.* Expansion of this basin did not occur due to flooding. Basal sediments of the edge core are more terrestrial in nature and indicate that basin expansion occurred via paludification. *Sphagnum* dominated bog vegetation was attained quickly after the earlier sedge dominated poor fen community.

Site 35

This shallow basin expanded in size due to flooding. The earliest peat forming communities are aquatic (Fig. 32), but lack any gastropod shells that indicate a permanent water body (Clarke 1981). Low abundance of woody elements and high abundance of *Carex* fossils indicate that the upper peats of these cores are derived from marsh vegetation that lacked significant shrub cover.

Figure 32

ELK ISLAND NATIONAL PARK SUMMARY PEATLAND DEVELOPMENTAL PROFILES



Site 48

Site 48 is presently situated adjacent to one of the larger lakes in Elk Island National Park. Lowered lake levels at the time of peat initiation are indicated by the presence of *Ruppia maritima* and *Zannichella palustris*. These species are normally found only in more saline conditions (Stewart and Kantrud 1972, Moss 1983, Husband and Hickman 1985). Lake levels rose, expanding the basin of the lake flooding the edges and initiating peat development. A permanent water body is suggested at the time of initiation by the presence of *Amnicola limosa* and *Menetus cooperi* shells (Clarke 1981). At both cores (Fig. 32), aquatic communities gave way to *Carex* dominated marsh communities This was followed by the invasion of woody shrubs and trees, to produce a swamp community. Lake levels rose a second time killing the tree and shrub vegetation at center core. Recently a *Typha* mat has developed around the lake, as evidenced by the sudden rise of herbaceous material in the top 5 cm of the core. Rising lake levels have appeared insufficient to disturb the edge core, which is located some distance from the present shoreline.

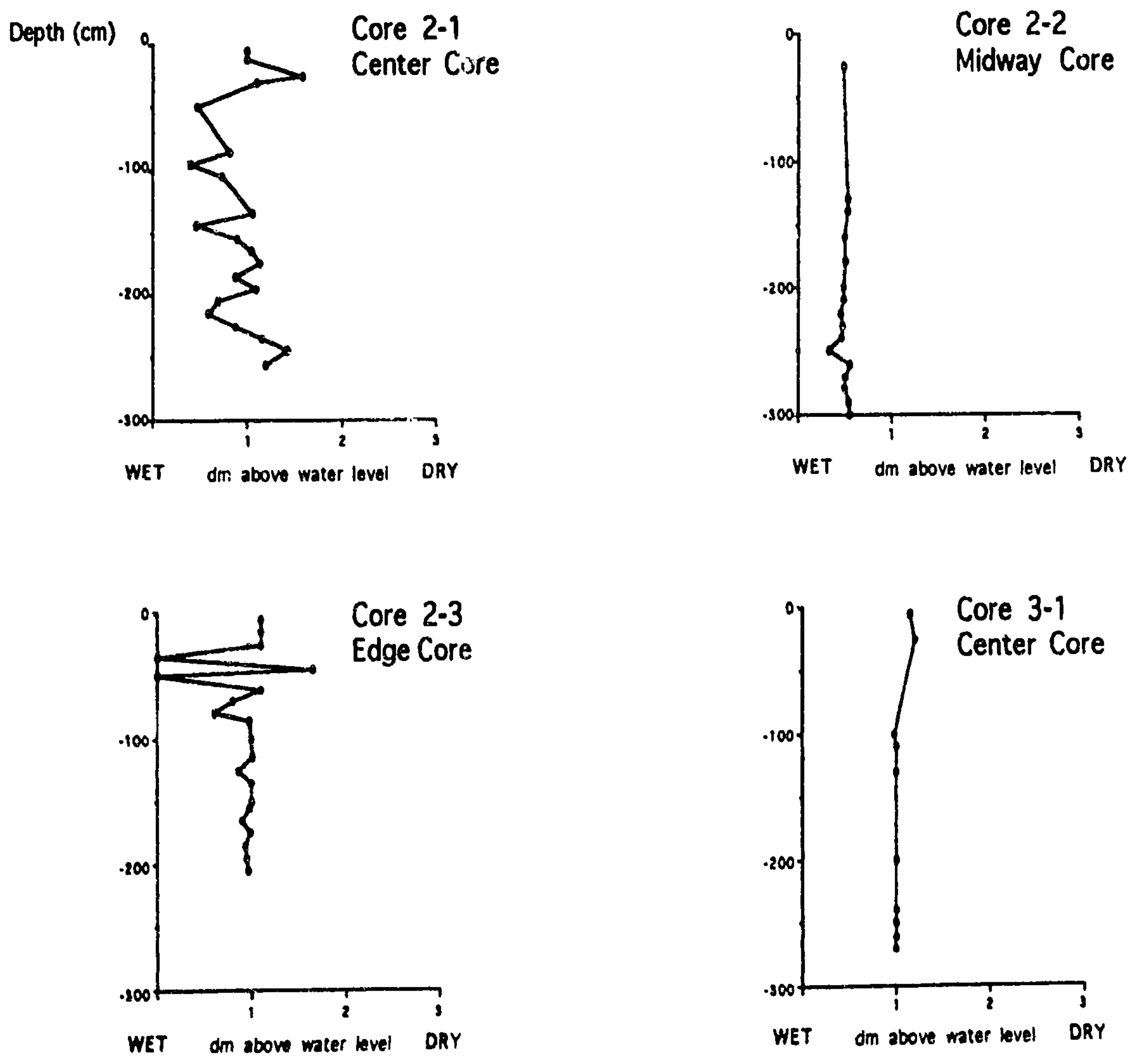
Paleoenvironmental Reconstructions

Inferred height above water table profiles in the fens at Elk Island (Fig. 33) indicate conditions have been quite variable in the past. Cores 2-2 and 3-1, suggest a relatively stable existence, where as 2-1 and 2-3, have experienced greater water table fluctuations. Surface height above water table conditions are similar to initial inferred height above water table, indicating that the floating mats

FIGURE 33

PALEOENVIRONMENTAL RECONSTRUCTIONS

Inferred Height Above the Water Table - Fen Profiles



have not stabilized. Surface vegetation is still subjected to fluctuations in the local groundwater hydrology. Inferred height above water table profiles of the bogs at Elk Island National Park indicate that the surface became gradually drier at site 27 (Fig. 34). Surface vegetation here has been removed from groundwater influences and is no longer subjected to local flooding. Surface conditions have become significantly wetter at core 22-2 in the top 40 cm. This reflects the recent flooding which has occurred at this core.

Inferred pH profiles in the fens at Elk Island National Park (Fig. 35) indicates that acidification has not progressed significantly at these sites. Inferred surface pH values are similar to inferred basal pH values. Inferred pH profiles of the bogs (Fig. 36) demonstrates that acidification from basal pH values of 5.5 to 4.4 (Core 27-1) and 4.8 to 4.2 (Core 22-1) has taken place with an abrupt change occurring as the peatland changes from moderate-rich fen vegetation into poor fen. Disturbance of the profile at site 22 due to flooding is apparent in the top 40 cm.

The paleoenvironmental reconstructions of inferred pH of site 27 are similar to reconstructions of bogs from Saskatchewan and Manitoba (Kuhry *et al.* 1992). At Mariana Lakes (Nicholson and Vitt 1990) inferred pH curves gradually declined during the transition from fen to bog. Paleoenvironmental fen curves at EINP are similar to Mariana Lakes in that fluctuations have occurred in the past but no general trends or net changes are evident.

FIGURE 34
PALEOENVIRONMENTAL RECONSTRUCTIONS
Inferred Height Above the Water Table - Bog Profiles

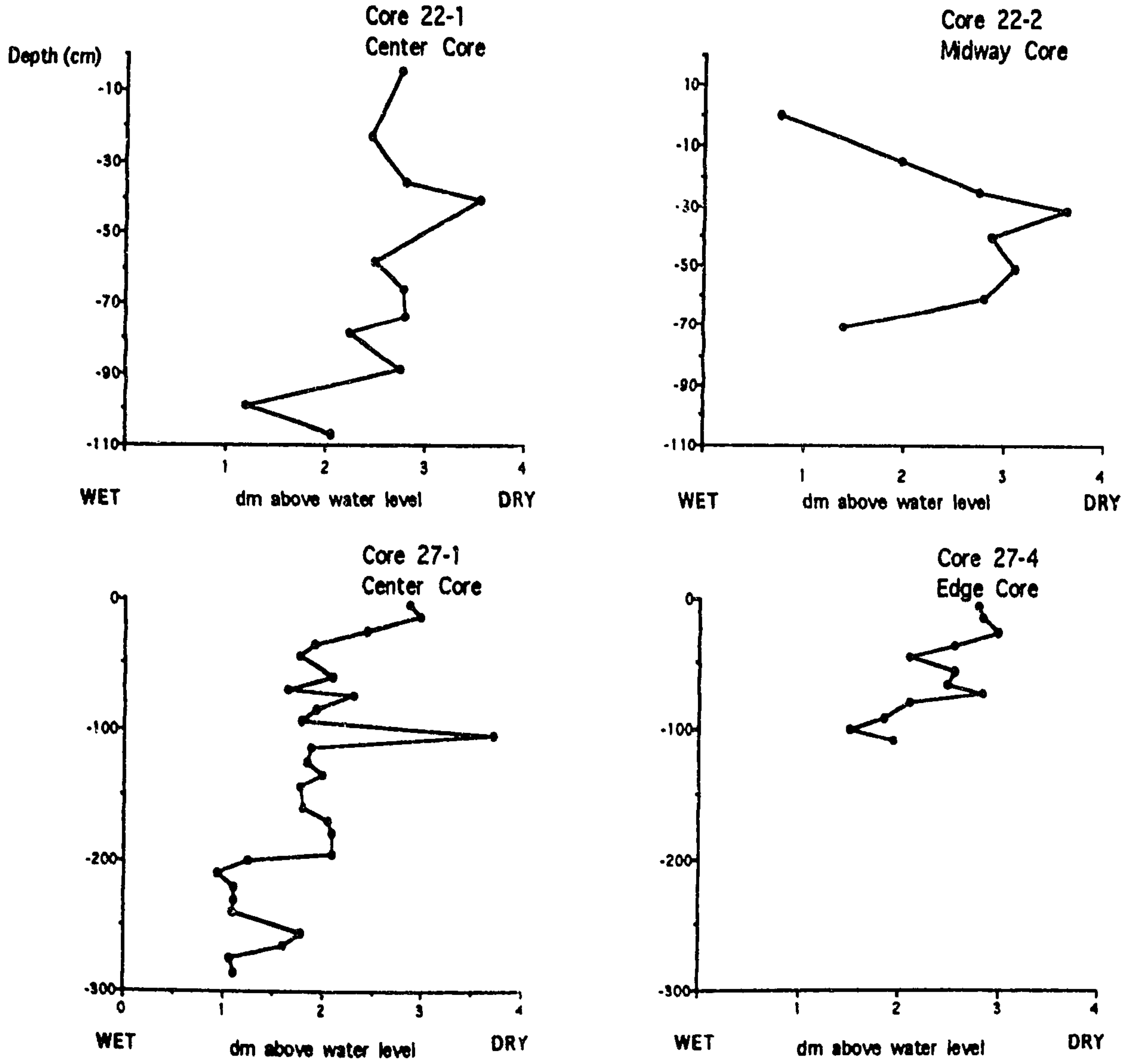


FIGURE 35

PALEOENVIRONMENTAL RECONSTRUCTIONS

Inferred pH Profiles - Fens

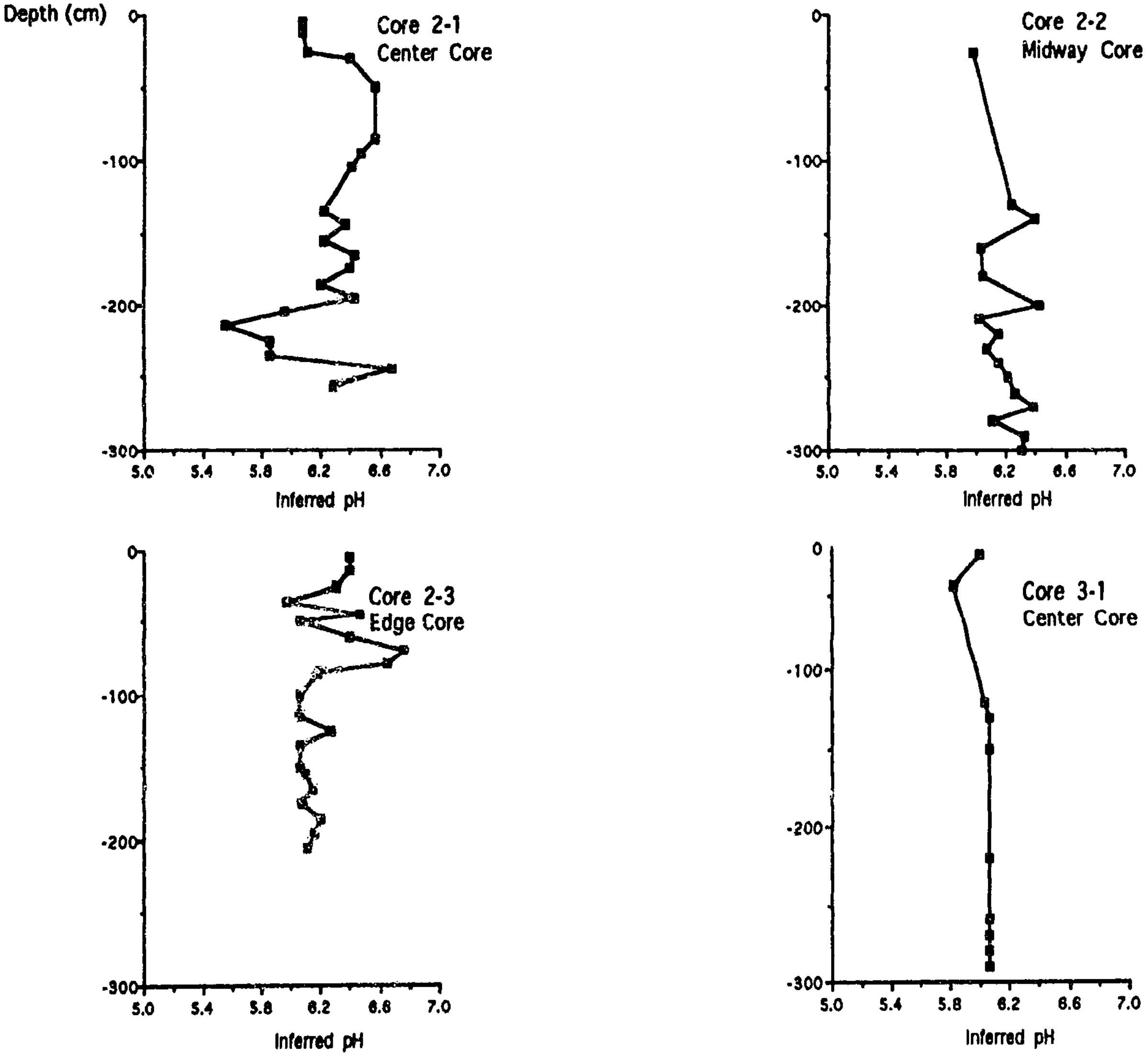
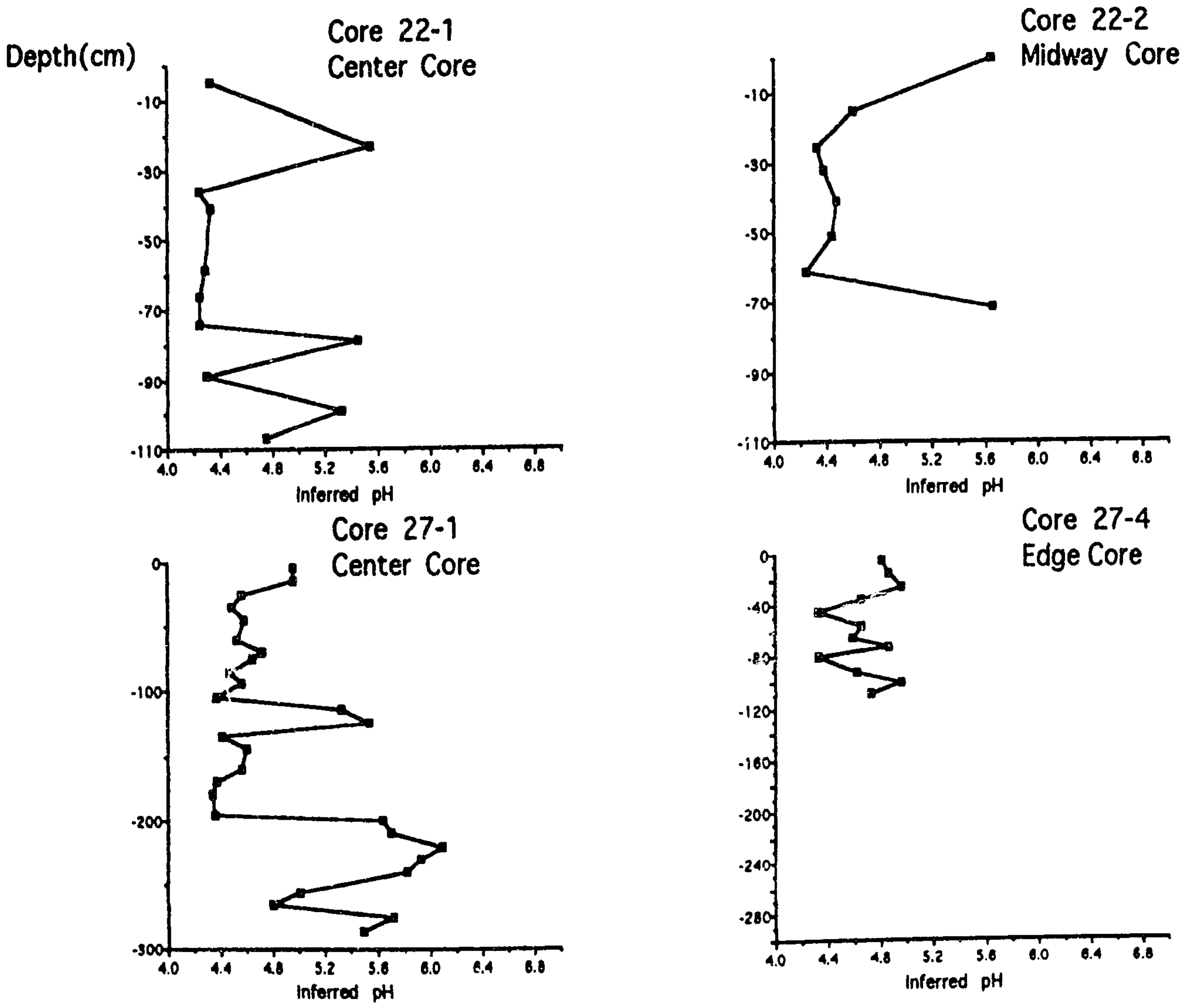


FIGURE 36

PALEOENVIRONMENTAL RECONSTRUCTIONS

Inferred pH Profiles - Bogs



Comparisons to Published Literature

In an effort to study climax successional communities and undertake pollen studies, paleoecologists have overwhelmingly directed their attention upon *Sphagnum* bogs. Few stratigraphic studies have been undertaken in fens (Zoltai and Johnson 1985, Janssen 1988, Janssens *et al.* 1992, Kubiw *et al.* 1989, Nicholson and Vitt 1990), marshes and swamps (National Wetlands Working Group 1988).

A summary of several published peat profiles for terrestrialized bogs is presented in Table 9. At each site, basal macrofossils of submerged aquatic plants or emergent marsh vegetation were identified. Common aquatic plants in Table 9 are *Chara, Potamogeton, Sparganium, Scirpus, Eleocharis, Myriophyllum, Najas, Nuphar, Nymphaceae,* and *Pediastrum.* Most of these sites also contain bryophyte remains such as *Sphagnum cuspidatum, S. subsecundum, S. warnstorfii, Drepanocladus revolvens, D. vernicosus, Scorpidium scorpioides, Calliergon trifarium,* and *C. giganteum.* Important early colonizers of the bogs at Elk Island National Park are the aquatic plants *Myriophyllum, Certatophyllum, Potamogeton, Chara, Typha, Najas,* and *Rumex.* Bryophytes of significance are *Sphagnum warnstorfii, S. angustifolium, S. magellanicum, S. squarrosum, Drepanocladus exannulatus, D. aduncus,* and *Calliergon stramineum.* Peat profiles in Table 9 that contain bryophyte fossils in the basal aquatic sediments tend to develop directly into fens. Alternatively a section of pure sedge peat can occur directly after aquatic sediments before any bryophytic remains become significant

Table 9

Gypsumville Manitoba 51°46'N 98°30'W Kuhry et al. 1992	La Ronge Saskatchewan 54°58'N 105°16'W Kuhry et al. 1992	Porcupine Mount. Manitoba 52°31'N 101°15'W H. Nichols 1969	Gleason Michigan 45°33'N 84°42'W Miller and Futyma 1987	Point Escuminac New Brunswick 47°04'N 65°50'W Warner et al. 1991(b)	Trewartha Ontario Warner 1989	Hook Lake Wisconsin 43°15'N 89°30'W Winkler 1988	Lake 16 Michigan 46°N 84°W Futyma and Miller 1986	Old Crow Yukon 68°N 139°30'W Ovenden 1985
FORESTED BOG Picea Sph. fuscum Polytrichum str. Pohlia nutans	FORESTED BOG Picea Sph. fuscum Sph. magellan. Polytrichum str.	FORESTED BOG Sphagnum Ericales	OLIGOTROPHIC BOG Sph. recurvum Chamaedaphne	BOG Kalmia Sphagnum fuscum	BOG Sphagnum Carex	SPHAGNUM BOG Sphagnum	MAT PEAT Sphagnum Carex Ericales	TUSSOCK TUNDRA Picea Rubus Chamaemorus Sph. Sect. Cuspidata Sph. Sect. Acutifolia
FORESTED FEN Sph. warnstorfii Tomenth. nitens Aulacom. palustre Ledum groenland. Larix laricina Picea richardsonii	FORESTED FEN Larix laricina Picea Campylium stellat. Tomenth. nitens Sph. fuscum	BOG Sphagnum				BRASENIA POND Typha Sagittaria Cyperaceae		SPHAGNUM CARPET Sph. obtusum Sph. squarrosum Cyperaceae Chamadaphne Drep. exannulatus Calliergon
WET RICH FEN Carex Drep. aduncus Calliergon gigant.	FORESTED RICH FEN Larix laricina Carex Calliergon gigant. Drep. lapponicus	POOR FEN Carex	RICH FEN Scorpidium scorp. Calliergon trif. Drep. revolvens Drep. aduncus Sph. cuspidatum Sph. subsecundum Sph. magellanicum	POOR FEN Andromeda Chamaedaphne Myrica gale Carex Menyanthes trif.	POOR FEN Sphagnum Carex	EMERGENT POND Typha	SEDGE PEAT Scorpidium scorp. Calliergon trif. Drepan. revolvens Meesia triquetra	MARSH/SEDGE MEAD. Carex aquatilis Carex rostrata Hippuris Eleocharis Ranunculus scleratus
SHALLOW POND Chara Typha Potamogeton Scirpus Carex Sph. warnstorfii	MARSH Typha Carex Rumex Larix laricina Calliergon gig. Sph. warnstorfii	MARSH Carex	SHALLOW POND Typha Potamogeton Eleocharis Scirpus Carex Glyceria canadensis	SHALLOW POND Potamogeton Pediastrum Drep. vernicosus Drep. revolvens Scorpidium scorp. Equisetum	FEN Carex Cladocera Diatoms Nyphaceae sponges mosses	EMERGENT MARSH Typha Carex	GYTTJA Najas flexilis Pediastrum aquatic plants	LAKE Chara Potamogeton Myriophyllum Nupher Ranunculus aquatilis
		POND Typha Sparganium Potamogeton						
Basal Radiocarbon Dates								
4230	5020	6700	8000	10,900	7,000	13,000	6210	

Basal radiocarbon dates and peat stratigraphic profiles of published terrestrialized bogs in North America. Major successional stages and macrofossil species are indicated.

(Griffin 1977, Tallis 1983, Ovenden 1985, Giller and Wheeler 1988, Janssen 1988, Wilcox and Simonin 1988). The centre core at site 22 (core 22-1) at Elk Island National Park has a similar stratigraphy, about 20 cm of pure sedge peat was laid down before bryophytes became present in the sediments. Floating sedge mats which can act as the primary colonizers of open water bodies do not occur in this area, but are prevalent in England and Scotland (Tallis 1983). The occurrence of vascular plants without a significant bryophyte cover indicates a period of fluctuating water tables and drawdown conditions, two contributing factors preventing bryophyte dominance in present day marshes. Once fen vegetation becomes established, autogenic factors contribute to increased oligotrophy, acidification and peat build up, creating drier, less cation-rich surface conditions. *Sphagnum* often invades, first creating *Sphagnum* dominated poor fens and bogs (Nichols 1969, Ovenden 1985, Winkler 1988, Warner 1989). This is followed by the establishment of shrubs and trees (Nichols 1969, Ovenden 1985), creating forested bogs. Often the two processes occur together and major successional changes occur in the peat profiles (Futyma and Miller 1986, Miller and Futyma 1987, Warner *et al.* 1991b).

The peat profiles of terrestrialized bogs at Elk Island National Park and those presented in Table 9, outline a hydrarch successional series of open pond/marsh - fen - bog. Within each profile there is evidence of increasing oligotrophy, acidification, and surface desiccation. This pattern of terrestrialization is supported by Vitt and Kuhry (1992), Warner *et al.* (1991b), National Wetlands Working Group (1988) and in a model presented for boreal peatland development by Osvald (1 outlining general mire development in the Edmonton, Alberta area. Similar developmental patterns have been recorded in the Red Lake peatland (Janssens 1988), in south Sweden (Mörnsjö 1968), in Finland (Warén 1924), and in Colombia (Kuhry 1988).

Fens are often considered to be a seral stage leading to bog development, although many fens have been stable ecosystems for thousands of years (Zoltai and Johnson 1985, Kubiw *et al.* 1989, Nicholson and Vitt 1990). Macrofossil community changes in fens have been attributed to autogenic change, climatic factors, and hydrology. Surface patterning is considered to be a secondary event in fens (Foster and Fritz 1987, Kubiw *et al.* 1989), as well as in bogs (Foster *et al.* 1988). A stratigraphic profile from a basin fen near Jan Lake, Saskatchewan (National Wetland Working Group 1988) indicates that this wetland began as a pond that was filled in by an open fen. Subsequently the open *Carex* fen was invaded by shrubs and tamarack trees. *Sphagnum* became predominant in the macrofossil record only in the last 28 cm. Similarly the development of shrubby vegetation followed by treed vegetation did not occur in a Rocky Mountain House fen until relatively recently (after 2350 yBP) (Zoltai and Johnson 1985). Fens at Elk Island National Park have developed very slowly from shallow open water basins. Aquatic plant remains are present in the peat sediments until the last 100 cm. It appears that development took place via the gradual encroachment of floating mats over the open water bodies. Bryophytes, particularly *Drepanocladus aduncus, D. crassicostatus, Calliergon* spp., and *Meesia* spp., were important components of the mat. *Carex* and shrubs are more recent additions to the peat forming communities. Inferred pH and water table reconstructions indicate that some of the peatlands in EINP are relatively stable, with autogenic processes occurring slowly, or arrested due to associated allogenic factors.

Swamp profiles from eastern Canada (Glooschenko and Grondin 1988), particularly a profile from Puslinch township, indicate that swamps can evolve from shallow marshes or ponds. Aquatic peats developed into sedge peats, followed by woody swamp peats. An identical series of seral stages has been described from Woody Bog, a *Populus/Salix* dominated wetland located just south of Grand Prairie, Alberta (A. Beaudoin, personal communication). Aquatic peats were replaced by sedge peats, followed by swamp peats. A similar "bog sere" was reported in Wisconsin by Frolik (Tallis 1983). He described a hydrosere consisting of aquatic plants followed by successive zones of *Typha/Scirpus/Phragmites*, *Carex* meadow, scrub (*Salix, Betula*), and finally *Populus tremuloides.* In the two undisturbed swamp profiles at Elk Island Park these seral sequences can also be seen. Bryophytes are rarely present in the sediments, and *Carex* dominated vegetation establishes early. This indicates that drought and drawdown play a significant role in the establishment of these communities.

Peat Chemistry Comparison to Published Literature

As compared to other reported publications on peat chemistry (Table 10), the bogs at Elk Island are high in ash (6%), sulphur and potassium, but average in calcium, magnesium, manganese, iron, and

Table 10

	A	B	C	D	E	F	G	H	I	J	K	L
1	Wetland	Description	Reference	% Ash	Ca mg/kg	Mg mg/kg	Mn mg/kg	Fe mg/kg	Na mg/kg	S mg/kg	P mg/kg	K mg/kg
2	Bog	Domed-Ontario	Can. Wetlands W. Group, 1988	2.0-4.7	800-9300	130-2220	50-160	72-1280	60-120		230-620	170-760
3	**	Boreal-Ontario	Can. Wetlands W. Group, 1988	1.8	1200	200		300			600	200
4		Boreal, Domed, Ont.	Can. Wetlands W. Group, 1988	2.6	1890	210	62	450	114		380	390
5	**	Northern, Plateau, Manitoba	Can. Wetlands W. Group, 1988	1.4-4.5	1737-6769	1146-4619		435-1369		566-2478	183-620	
6	**	Flat Bog, Manitoba	Can. Wetlands W. Group, 1988	1.4-5.2	1213-10129	629-4373		436-1581		293-3502	115-451	
7	**	Basin Bog, Manitoba	Can. Wetlands W. Group, 1988	3-10.7	1593-20230	708-2574		429-2516		310-764	313-825	
8	**	Mariana Lakes, Alberta	Nicholson, 1989	4.1	4983	442	30	1052	119	676	298	128
9	**	Open Bog, Northwestern Ont	Riley and Michaud, 1989	4.8-6.4	5500	<1250	<150	<2500		<375	600	1250-2000
10	**	Treed Bog, NW Ont	Riley and Michaud, 1989	4.7-6.3	3000-4500	1250	<150	<2500		<375	<600	<2500
11	**	Sphagnum, Coom Rigg Moss	Chapman, 1964	2.0-4.0	1000-5000			1000-4000	500			250
12		Bog Plateau	Damman and Dowhan, 1981	3.1-4.1	700-3500	1100-1700			370-980		390-1820	90-2190
13		Scandinavian	Damman, 1978	< 4	4000-16000	6000-10000	0-100	250-3000	200-600		200-800	0-3000
14		Bog peats above water table	Zoltai and Johnson, 1985		4125	814		724	92	831		587
15		Sphagnum	Pakarinen and Gorham, 1983	3.0-7.0	1194-3873	356-798	8-541	501-2561	19-121	540-2910	246-651	242-2103
17		Sphagnum	Pakarinen, 1987	1.2-3.1	1480-2700	300-825	175-950	200-1200	80-475			
18		Oligotrophic	Zoltai and Johnson, 1987		2724	1006	146	1352	119	602	522	1276
19												
20	Poor Fen	Open, Ontario	Can. Wetlands W. Group, 1988	3.9	2400	390	120	1410	130		700	570
21		Boreal, Ontario	Can. Wetlands W. Group, 1988	3.3	2400	400		1400			700	600
22		Boreal, Cochrane, Ont.	Can. Wetlands W. Group, 1988	3.3	5420	530	30	480	142		690	650
23			Damman and Dowhan, 1981	3.5	800-1600	700-1100			340-1010		480-910	230-3170
24			Damman and Dowhan, 1981	8.7	800	300-1300			290-1010		640-960	340-3310
25		Oligotrophic	Zoltai and Johnson, 1987		3298	918	154	1992	237	890	736	1606
26	Fen **	Northern, Plateau, Manitoba	Can. Wetlands W. Group, 1988	5.2-11.7	9765-21531	4610-7585		629-6018		6905-16377	348-442	
27	**	Boreal, Manitoba	Can. Wetlands W. Group, 1988	5-18.7	4749-18074	2617-8255		582-3640		1701-14312	435-1736	
28	**	Flat Bog, Manitoba	Can. Wetlands W. Group, 1988	5-8.9	12012-1844	3095-4302		1472-5778		3056-4246	269-521	
29	**	Horizontal Fen, Alberta	Can. Wetlands W. Group, 1988	8.2-15.1	9927-35602	4746-7304		831-7657		1814-22936	618-1508	
30	**	Northern Ribbed, Alberta	Can. Wetlands W. Group, 1988	10.1-54.3	37341-1893	1445-3257		4197-14533		1641-4875	412-570	
31	**	Collapse scar, Manitoba	Can. Wetlands W. Group, 1988	8-17.3	10762-2909	1802-3567		7032-17014		2708-8115	405-4379	
32	**	Basin Fen, Saskatchewan	Can. Wetlands W. Group, 1988	5.9-11.1	7798-21575	1475-2966		1154-11084		707-2695	440-1166	
33	**	Mariana Lakes, Alberta	Nicholson, 1989	12	9332	887	102	2189	152	2255	836	341
34		Poor fen	Vitt and Chee, 1990	3-3.8	3241-4086	471-1004		368-800	124-227	1034-2679	851-1307	278-640
35		Mod-rich fen	Vitt and Chee, 1990	10-12.1	14018-1742	1791-2222		880-1074	214-737	3348-8267	1263-1918	403-1597
36	**	Open Fen	Riley and Michaud, 1989	7.6-10.7	16000-2400	1250-2500	100-1400	6250-11250		<375	450-700	<2500
37		Mesotrophic	Zoltai and Johnson, 1987		18380	3480	708	4116	177	1920	861	1080
38		Dystrophic	Zoltai and Johnson, 1987		8699	1803	369	3432	202	1147	812	1863
39	**	Treed Fen	Riley and Michaud, 1989	6.8-10.6	15000-3300	<2500	100-500	3000-6000		<375	375-750	<2000
40	Rich	Michigan	Richardson et. al, 1978	28.6	1330	140					90	80
41	**	Wagner Bog, Alberta	Can. Wetlands W. Group, 1988	20.7-47.7	55273-1454	3915-5333		321-8027	445-849	3458-23880		
42		Extreme rich fen	Vitt and Chee, 1990	10.6-11.5	48780-5139	3830-4518		810-1283	158-193	9364-6788	550-632	599-703
43		Macrotrophic	Zoltai and Johnson, 1987		44657	3410	796	7677	122	2757	801	644

Table 10 continued.

	A	B	C	D	E	F	G	H	I	J	K	L
44	Wetland	Description	Reference	% Ash	Ca mg/Kg	Mg mg/Kg	Mn mg/Kg	Fe mg/Kg	Na mg/Kg	S mg/Kg	P mg/Kg	K mg/Kg
45	Marsh	Floating marsh/fen, Ontario	Can. Wetlands W. Group, 1988	24	6080	1200	30	4610			920	3870
46		Floating marsh/fen, Ontario	Can. Wetlands W. Group, 1988	23	15020	2260	120	9080			680	4740
47		Shallow shore, Ontario	Can. Wetlands W. Group, 1988	45	6780	3530	180	12300			870	8630
48		Sparganium marsh, Quebec	Can. Wetlands W. Group, 1988	89								
49		Meadow marsh, Ontario	Can. Wetlands W. Group, 1988	39	5900	3090	60	9330		950	6910	
50	**	Meadow Marsh	Riley and Michaud, 1989	8.2-18.9	18000-2250	3800-4250	150-2250	3600-7500		<350	450-1350	600-3500
51		Phragmites, Coom Rigg Moss	Chapman, 1964	6.0-12.0	6000-10000			2000-5000	250			:00
52	Swamp	Conifer	Zoltal and Johnson, 1987		23120	3539	464	2596	128	3046	316	1071
53		Boreal, Conifer, Cochrane, Or	Can. Wetlands W. Group, 1988	7.2-7.9	21600-2420	1300-4100		2200-13100			400-600	490-7800
54		Deciduous, Ontario	Can. Wetlands W. Group, 1988	7.9	21600	1310	110	2230	100		430	430
55		Shrub, Timmins, Ont	Can. Wetlands W. Group, 1988	9	24100	1720	101	1860	91		30	420
56		Coniferous, Manitoba	Can. Wetlands W. Group, 1989	9.7-15.5	5365-14045	1654-1680		1735-3816		660-754	616-809	
57		Picea Mariana, Quebec	Can. Wetlands W. Group, 1988	17								
58		Thuja occid., S.Quebec	Can. Wetlands W. Group, 1988	62-65								
59		Shore swamp, Quebec	Can. Wetlands W. Group, 1988	93.9								
60	**	Thicket Swamp	Riley and Michaud, 1989	6.2-9.3	17000-2800	4675-5525	250-1250	2125-6800		350-700	600-1300	<3265
61												
62	Aquatic	Riverton, Manitoba	Can. Wetlands W. Group, 1988	43.4	16631	9494		13303			434	
63	**	Jan Lake, Saskatchewan	Can. Wetlands W. Group, 1988	21.5-64.4	12529-2543	1475-12402		1528-31174		1915-10042	392-528	
64												
65	Published peat chemistry (% ash, calcium, magnesium, iron, sulphur, phosphorus, potassium) from North American and select European peatlands.											
66	** Indicates publications that included a depth profile of the peat chemistry.											
67												

sodium. The poor fens are mineral rich as ash, calcium, magnesium, iron, and sulphur are high (Table 7) compared to published reports (Table 10). The peat chemistry of the moderate-rich fens is comparable to published peat chemistry data (Table 10). Rich fens tend to have much higher calcium and magnesium concentrations. Reported peat chemistry of marshes indicates that they commonly have much higher ash and phosphorus concentrations than at Elk Island, but lower calcium, sodium and sulphur. Swamp peats appear to be extremely variable in ash content ranging from 7-94% (Table 10). Other reported parameters are also extremely wide ranging. In comparison, the swamps at Elk Island are low in ash and iron, but high in calcium, magnesium, sodium, sulphur, and phosphorus. Although aquatic peats have not been adequately documented chemically, the aquatic peats at Elk Island are comparable to two sites analyzed by the National Wetlands Working Group (1988, Table 10).

Peat Profiles

Physical Profiles

Ash

In an aquatic environment, mineral grains are incorporated into the sediments through wave action and lake turnover. As peat accumulates, accessibility to mineral soil in the basin is reduced (Shotyk 1986), particularly if a floating mat is formed. The floating mat provides a physical obstruction to the circulation of lake water into the peat forming community. With the accumulation of significant quantities of peat, waterflow into the peatland becomes increasingly restricted to the lagg and major flow channels (Tallis

1983) further reducing allogenic sources of ash. The ash content of mire plants reflect both allogenic and autogenic sources. Minerotrophic mire species contain higher quantities of mineral matter derived from the water source, than corresponding bog plants (Chapman 1964, Mörnsjö 1968, Pakarinen and Tolonen 1977, Karlin and Bliss 1984, Shotyk 1986). As the peatland develops ombrotrophic conditions, incoming sources are reduced to aerially deposited forms (Gorham 1957, Damman 1978, 1986), and biogenic silica produced by the plants themselves (Shotyk 1988).

Ash profiles from terrestrialized bogs and fens have high ash contents (5-49%) in the basal aquatic sediments (Gorham 1949, Chapman 1964, Mörnsjö 1968, Kubiw 1987, Nicholson 1989) Once these peatlands have developed fen peat, ash contents drop to lower levels. Ash profiles from paludified fens have high mineral contents in the lowermost samples adjacent to the mineral soil boundary, after which, ash levels remain fairly constant at levels which reflect the amount of minerotrophy in the fen (Chapman 1964, Zoltai and Johnson 1985, Kubiw 1987, National Wetland Working Group 1988, Nicholson 1989, Riley and Michaud 1989). Ash profiles from paludified bogs commonly have very low ash contents that extend until basal soil sediments are reached (Chapman 1964, Sonesson 1970, Nicholson 1989). Allogenic sources of ash to paludified bogs are either insignificant or ash is leached out from the peat soils after deposition. Ash profiles of swamps and marshes tend to have consistently high ash content, with a few profiles showing a decrease towards the peat surface (National Wetland Working Group 1988, Riley and Michaud 1989) indicating a consistent mineral source.

Ash profiles from the wetlands of Elk Island National Park are typical of terrestrialized peatlands and indicate the gradual removal of the aquatic peat forming community from lake generated sources of ash. Bog site 27 has an ash profile that is slightly different from the others; ash percentages drop very quickly from greater than 50% in the aquatic peats to 4% in the fen peats. This ash profile is typical of a paludified peatland, and suggests that during development site 27 quickly became isolated from lake generated ash sources.

Bulk Density

Bulk density is affected by the species composition of the peat, it's degree of consolidation and compaction, and the state of decomposition. Undecomposed *Sphagnum fuscum* peat has a bulk density of 0.02 g/cm^3 (Pakarinen and Gorham 1983) which compacts to bulk densities of 0.08 g/cm^3 60 cm below the surface. Bulk density profiles generally increase with depth (Zoltai 1991). At bogs in northwestern Ontario, surface peats averaged 0.08 g/cm3, while basal peats averaged 0.21 g/cm^3 (Riley and Michaud 1989). In comparison bulk density values at the surface of bog site 27 average 0.04 g/cm^3, while below surface poor fen and moderate-rich fen peats ranged from 0.1-0.25 g/cm^3, and aquatic peats are generally greater than 0.2 g/cm^3. At bog site 22, poor fen and transitional peats had bulk densities of 0.2 g/cm^3, and aquatic peats range from 0.2-1.9 g/cm^3.

Bulk density profiles of a terrestrialized fen in Ontario have surface values of 0.02 g/cm^3, which increased to 0.6 g/cm^3 at depth. Lower aquatic gyttja sediments had bulk density values ranging from

0.4 to 1.4 g/cm^3 (Warner *et al.* 1991a). At Mariana Lakes, the terrestrialized poor fens have surface bulk densities averaging 0.1 g/cm^3, gradually increasing to 0.8 g/cm^3 in the aquatic peats (Nicholson 1989). At Muskiki Lake, a terrestrialized fen, bulk densities in the surface peats average approx. 0.08 g/cm^3. In the aquatic peats of this section, bulk density values averaged 0.4 g/cm^3 (Kubiw 1987).

Bulk density profiles from the fens at Elk Island clearly demonstrate the gradual evolution of these peatlands from aquatic ecosystems with high bulk densities in the aquatic peats and low in the fen peats, and the presence of a floating mat. Fen profiles clearly show the development of floating mats. Surface peats in the fens generally have greater than 0.2 g/cm^3, quickly declining in cores 2-1, 2-2, 3-1, 3-2, to less than 0.1 g/cm^3. This marks the boundary between the floating mat peat and detrital peat shed from the bottom of the floating mat that accumulated on the pond bottom. Between the two types of peat is a section of detrital peat which has not been compacted. This zone of uncompacted detrital peat is not seen in the edge cores as the mat is grounded from the time of initiation.

Swamp and marsh profiles at Elk Island show the same general trend as the bogs and fens: a gradual removal of the wetland from an aquatic ecosystem, as evidenced by a decline in bulk density values from aquatic peats to surface peats. The bulk density values given here compare favorably with values given by Riley and Michaud (1989).

Chemical Profiles

Calcium

In ombrotrophic, terrestrialized peatlands calcium profiles are highest at the base and decline gradually to < 5,000 mg/Kg once ombrotrophic peat begins to form (Chapman 1964, Damman 1978, National Wetland Working Group 1988, Riley and Michaud 1989). Basin fens (formed under terrestrialized conditions) have similar profiles (Kubiw 1987, National Wetlands Working Group 1988, Nicholson 1989). Paludified bogs often have calcium profiles, which are calcium poor from the beginning of peat formation (Chapman 1964, Nicholson 1989). Horizontal fens that have continuous water flow through them have straight, consistently high calcium profiles (Zoltai and Johnson 1985, National Wetlands Working Group 1988, Nicholson 1989). In marshes and swamps where high decomposition rates occur and the vegetation is dominated by vascular plants that have penetrating roots, internal recycling of minerals maintains high concentrations of calcium throughout the profile (National Wetland Working Group 1988, Riley and Michaud 1989). There is also some evidence that as peat accumulates in these wetlands, minerals become increasingly limited (Chapman 1964).

In Elk Island, the calcium profiles of the central fen cores (2-1,2-2, 3-1, 3-2) show a terrestrialized calcium profile, with highly variable calcium levels in the aquatic peats, reduced levels through the transitional aquatic/fen peats, and stabilized values of 10,000 mg/Kg in the moderate-rich fen peats. Core 2-3 has a very stable profile, indicating that continuously low input of calcium from overland flow occurs at this site. Core 3-3 indicates that the input of calcium to this core has increased in the past but has decreased again following the development of swamp vegetation. Bog profiles, particularly site 27, suggest a limited calcium input into these sites, that has declined steadily during development. Edge core 22-3 has a high basal calcium concentration and a more variable profile, indicating an unstable hydrologic regime. Marsh site 35 has low basal calcium concentrations (10,000 mg/Kg) that increase towards the surface as marsh peats are encountered. Falling water levels, increased decomposition, and the recycling of calcium through vascular plant roots may all contribute to this core profile. Swamp site 48 has high calcium concentrations in the aquatic sediments that rapidly decline upon the appearance of marsh and swamp peats. In this site it appears that the lake basin has contributed significantly to the calcium levels. Once marsh vegetation became established this input was lost. With the development of a shrub layer, decomposition and internal recycling rates would increase, resulting in a rise in calcium in the surface peats.

Copper

Peatlands trap copper, due to the metal's strong affinity for organic material (Shotyk 1988). Largin *et al.* (1972) clearly demonstrated that copper concentrations in a lowmoor peatland followed a path of water movement into the mire. Concave shaped copper curves are common in the peat profiles of bogs and fens (Elomaa 1987, Riley and Michaud 1989). Surface enrichment is attributed to bioaccumulation or increased industrial pollution (Shotyk 1988). Surface concentrations of 6.3-12.7 mg/Kg were found in a paludified ombrotrophic peatland at Abisko (Sonesson 1970), and 2 mg/Kg in surface peats of a minerotrophic fen in Finland (Elomaa 1987). Basal sediments were 6.3 mg/Kg at Abisko and 8 mg/Kg in Finland. Copper profiles in bogs of northern Ontario are concave with approx. 3.8 mg/Kg at the surface and up to 56.3 mg/Kg at the base. Fens contain 1.8-5 mg/Kg at the surface and 9-24 mg/Kg at the base. Swamps and marshes tend to have straight profiles with copper contents averaging 6-9 mg/Kg (Riley and Michaud 1989).

Fen profiles at Elk Island show some tendancy towards being concave with secondary surface enrichment due to either bioaccumulation or pollution. Once again the central fen cores show strong evidence of high input during the initial aquatic stages, gradually declining once floating mats formed, limiting the minerotrophic water sources. Edge cores suggest continuous low copper inputs into these sites. Bog site 27 has a profile that indicates the initial sediments were in contact with a copper source (overland flow, lake sediments), that quickly became eliminated. Bog site 22 has a variable copper profile, indicating that initial sources were low, but copper inputs have increased at least twice during the development of this peatland. Copper profiles in the swamps and marshes are similar to their calcium profiles. Site 35 has low basal values, which peak in the aquatic/marsh sediments. Site 48 has high basal copper concentrations, which decline towards the peat surface, indicating a gradual decline has occurred in the amount of copper reaching these peats.

CONCLUSIONS

Thirteen wetland vegetation groups were found to occur in Elk Island National Park. They range from saline marshes through to forested bogs. Vegetation is predominantly controlled by waterflow and cation gradients reflected in strong correlations between vegetation, pH, corrected specific conductivity, calcium, magnesium, and sodium content of the surface waters. Nutrient (nitrogen, phosphorus) content of surface waters does not play as strong a role in determining species composition of these peatlands. Marshes, swamps, and moderate-rich fens at Elk Island National Park are circumneutral in pH, with surface waters high yet variable in calcium, magnesium, and sodium. Phosphorus levels can be high in some types of swamps. Poor fens and bogs are acidic, with less mineral ion content. Nitrate, ammonium, and phosphorus levels in bogs and poor fens can be as high or higher than the marshes, moderate-rich fens, and swamps. Elevation, number of inlet and outlet streams, water level, and hummock height all contribute to the diversity and composition of species in these wetlands.

Successional patterns in the wetlands follow hydroseral successional sequences outlined by Walker (1970). Two definite developmental pathways can be found within the park.

1) Aquatic -- Rich Fen -- Poor Fen -- Bog -- Forested Bog

2) Aquatic -- Marsh -- Swamp

When the site is conducive to bryophyte colonization, the direction of succession is towards *Sphagnum* domination. Autogenic factors drive this successional pathway by the reduction of the ionic supply reaching the wetland. Autogenic changes evident in these wetlands are the gradual elevation of the peat surface above the local water table, acidification of the environment, and oligotrophism. Peat accretion fills in the basin and leads to consolidation of the peat. Once the peat surface is no longer subjected to excessive water level fluctuations, bryophytes and shrubs can establish. Gradually hummocks are formed where the process of acidification and oligotrophism begins. Here in small microtopographic situations bryophytes lower the pH level (Glime *et al.* 1982, Gorham *et al.* 1984, Urban *et al.* 1987) due to their cation exchange properties. Organic acid production through decomposition may also be a factor (Hemond 1980, Gorham *et al.* 1984). Elevation from the surrounding watertable promotes leaching of nutrients and isolation from ionically rich waters. Amalgamation of the hummocks and channelling of water away from elevated portions of the mire expands the region affected by these two processes and ultimately leads to the formation of bogs.

Where drawdown or watertable fluctuations prevent bryophytes from establishing, the wetland develops into a swamp. Parallel trends, due to autogenic factors operate in marsh wetlands. Peat material deposited beneath the sedge community, isolates it from one ionic source, the underlying mineral soils. The layer of peat also acts as a stabilizer of hydrologic conditions, due to it's ability to swell and store water. Elevation of the marsh community from the local watertable occurs due to the accretion of peat. As a result severe flooding is restricted. Excessive desiccation is retarded by the ability of the peat to retain water. Consequently shrub and tree growth is promoted. If through hydrological stability the site becomes conducive to bryophyte establishment, mosses invade and the swamp community may evolve into a fen. Although this successional pattern has not been documented in Elk Island, it is well known elsewhere from the literature (Nichols 1969, Tallis 1983, Winkler 1988). It is likely the high evapotranspiration rates that occur in this region is responsible for limiting this successional pathway through limiting bryophyte establishment.

Climate is an allogenic factor that has strongly affected peatland development at Elk Island National Park. The early Holocene thermal optimum delayed peat initiation until after 6720 yBP. Early wetlands were small open ponds with *Typha* marshes occurring along the shorelines. The predominance of *Typha* marshes in early basal sediments is considered to be characteristic of southern boreal peatlands and indicative of warmer climates (Kuhry *et al.* 1992). Some wetland macrofossils present in the basal sediments normally occur in more saline conditions, perhaps a sign of higher evapotranspiration rates. *Sphagnum* invasion into the bogs at Elk Island National Park is delayed compared to more northern peatlands and is considered to be climatically induced (Kuhry *et al.* 1992). Terrestrialization has been the dominant process initiating peat development in the park. Climatic limitations and topographic relief presently prevent peatlands from extending out beyond small depressional basins. The relatively late invasion of *Sphagnum* and lack of paludified peatlands in the park indicate that climate is continuing to exert a strong influence on the development of these sites.

Climatic factors have affected peatland development at Elk Island National Park in several ways: 1) delay of peat formation immediately following deglaciation, 2) expansion of the peatlands basins between 6600 and 2910 yBP, 3) predominance of terrestrialized peatlands in the park, and 4) late invasion of *Sphagnum* into the bogs. These climatic factors have affected all peatlands uniformly over broad geographical areas and are thus not responsible for the diversity of peatlands that exist within the park.

Edaphic factors are more site specific and affect peatlands individually. They are the physical setting of a wetland such as elevation, basin morphology and hydrology. These factors influence the starting point (terrestrialization, paludification), and control the rate of development in a given peatland.

Autogenic factors occur within individual peatlands and appear to have three directions directly affecting succession. These are acidification, elevation of the peat surface, and oligotrophism.

Development of the peatlands at EINP has been studied using peat macrofossils and physical and chemical characteristics of the peat. Using this combined approach processes driving the evolution of the peatland have been elucidated. The profiles from the fens both chemically and physically indicate that minerals were abundant in the early peat forming shallow pond stage of these peatlands. Surface runoff, wave action, and lake turnover renewed the minerotrophic environment. Floating mats formed and the peat forming plant communities became increasingly more isolated from mineral sources.

Bog profiles indicate that a similar process occurred. An influx of copper, calcium and mineral matter occurred in site 22, after the infilling process began, while site 27 experienced rapid and almost complete removal from minerotrophic sources. Terrestrialization and oligotrophism processes can be seen in the chemical and physical profiles of swamps and marshes. Marsh site 35 experienced a rapid decline in ash and bulk density as development progressed from aquatic to marsh environments, with a corresponding increase in calcium and copper. Swamp site 48 experienced a gradual decline in bulk density, ash, calcium and copper from aquatic to marsh environments. Some surface enrichment is also seen, with the development of swamp vegetation that may be due to bioaccumulation from decomposition and recycling.

According to the discriminant analysis it is possible to identify peat types based upon chemical and physical characteristics. Sediments which are formed under aquatic environments have high ash and bulk density values (>20%, >0.15 g/cm^3), and high metal contents. Marsh and swamp peats have less than 20% ash, less than 0.15 g/cm^3 bulk density values, but contain more than 10,000 mg/Kg calcium. Marshes are slightly more mineral rich and eutrophic than swamps. Fens at Elk Island have less than 10,000 mg/Kg of calcium, and less than 12% ash in the peats, with bogs having under 5,000 mg/Kg calcium and less than 6% ash.

This thesis describes the development of wetlands at the southern limit of the Boreal Forest, where wetlands are restricted to small topographically defined shallow basins. Here terrestrialization has been occurring since 6700 yBP. North of this site, peatland development via terrestrialization is of less significance, as large areas of the landscape have become paludified (Sjörs 1961, Nicholson and Vitt 1990). Progression from fen to bog takes place much more quickly in these more northern peatlands as *Sphagnum* invasion occurs much more rapidly (Kuhry *et al.* 1992). Within the park boundaries a wide diversity of wetlands exist, ranging from swamps, saline marshes, fresh water marshes, moderate-rich fens, poor fens, and bogs. All of the wetlands in Elk Island began as small fresh water ponds with shore marsh vegetation along the edges. Edaphic factors not climate controls the diversity of wetlands within the park. Bog development has occurred in certain places and it's development is related to elevation, topography, basin configuration, hydrology, and stream flow. Severe watertable fluctuations prevent the establishment of bryophytes and peatland development progresses from marsh into swamp vegetation.

Beavers have affected the peatlands in EINP extensively by flooding the depressional basins. Fens, bogs, and marshes are inundated with mineral rich waters, and the peatlands regress to former successional stages. Many are completely covered creating ponds or marshes. The amount of impact which beavers have on these sites is dependant upon how high the water table rises. Fens, which have grounded central mats are most likely to be severely affected by beavers. Fens with grounded mats are: a) appealing to beavers (Robertus 1986), b) more sensitive to flooding because of the grounded mat, c) are diverse within the park (moderate-rich and poor fens), d) and are a relatively rare (aerially) wetland type in the park. Basins containing small open water bodies surrounded by floating mats are not likely to be impacted by beaver as dam building is limited and the floating mats merely rise with an increase in the water table. Bogs are least likely to be impacted by beavers as low water levels and dense black spruce forests are likely to discourage beavers. Bogs also tend to have few outlet streams, often none, which afford little opportunity for damming. Similarly swamps will be avoided due to the tall shrubs, shallow water tables and few streams. Effects of beavers on marshes (deep or shallow) will be the same as fens, reverting the marsh to previous successional aquatic stages.

Fire is another regular disturbance affecting wetlands within the park. It, however, has had little impact on the development of the wetlands. Only one of the six study sites contained any charcoal layers in the peat profile. All profiles at EINP indicate slow progressive development and do not show any disruptions or retrogressive changes that have occurred due to fire. Management of the wetlands at EINP should involve maintaining the exceptional diversity of wetlands within the park and should be directed towards controlling beaver populations or the negative impact of beavers in the park. A number of fens in the north east section of the park should be set aside and managed intensively to prevent beavers from colonizing and flooding these fens. Efforts should also be directed towards maintaining the few known saline springs and marshes as these are relatively rare in the park. Since fire has not had a significant impact of the development of wetlands in the park, the present practice of prescribed burning should continue.

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Appendix I
Site 2-2 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Depth(Cm	Mineral	LargDet	Herb	HerbRoot	CarexLimP	Myriophyll	Ceratophy	Potomoge	Sphag CUS	Sphag ter	DrepCrass	DrepPolyc	DrepRevol	DrepExann	DrepAdun	CallierTr	CallierGig	MesolTriqu	MeesiaLon	DrepAvK	DrepVerni
2	0-5		28	30	22	20																
3	10.0-12		15	25	36	15																
4	20-25		7	7	60.5	5										2					11	
5	45-50		4	20	71	5																
6	125-130		13	22	45	2														5		11
7	135-140		6	9	6	0.5														1		77.5
8	155-160		25	2	20										3	1		3		7	25	7
9	175-180		25	11.5	55											1.5				1.5	4	
10	185-190		67.5	20	5				0.5													
11	195-200		24.5	5	31	4			1					11		4				1	4	4
12	205-210		21.5	7	31.5	1			1						3	23	1		1		8	3
13	215-220	1	34	12	27	1			1							13	3		1.5	1.5	3	
14	225-230	0.5	20	3	15	1			0.5							42	5			10		
15	235-240	1	53	22	7			7	1							2	1			1	2	1
16	245-250		68	4	6	1	0.5	7	0.5							1	5			1	5	1
17	255-260		45		1	0.5		3	3			11	7			11.5		7			7	
18	265-270		25	10	45			1.5	0.5				3			5	2	2	2			2
19	275-280		30	4	23	1		5	1								1		2		32	
20	285-290	1	55	5.5	17	1.5		3.5	1				5			10	2			2		5
21	295-300		70	3.5	3.5			5	1			1	4			2	1				8	
22	305-310		80	1	1			13	1			0.5	1		0.5	1						
23	315-320	1	83	1			1	10	2							1						
24	325-330		87		1		1	9								0.5						
25	335-340		91				1	5	1			1				1						
26	345-350		80				1	16	2				1									
27	355-360	0.5	79	0.5			1	15	0.5	1	1					0.5						
28	365-370		92.5		0.5			5			0.5	0.5									0.5	
29	375-380		95		0.5			2	0.5													
30	385-390	0.5	45	0.5		0.5		51.5	1													
31	395-400		79			0.5		18	0.5								0.5			0.5		
32	405-410		68.5		1		1	27.5	1								0.5					
33	415-420	40	44.5		0.5			10	1.5		0.5						0.5					
34	425-430	1	92.5	0.5				2.5									0.5					
35	435-440	1	87		1.5			1														
36	445-450		88.5					2								0.5						
37	455-460	3	87		1			0.5	0.5			0.5			0.5		0.5			0.5	0.5	
38	465-470	2	91					1							0.5		0.5					
39	475-480	1	93.5					1														
40	485-490	2	88		1			0.5									0.5					
41	495-500	5	75.5		15			0.5														
42	502-507	10	81.5		5												0.5					
43	507-512	5	94																			
44	512-515	25	68.5					1														
45	525-530	5	94.5								0.5											
46	535-540	5	88.5					2														

Appendix I
Site 2-2 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
1	CallerStr	AmbiosSei	DrepSp	Picea	Wood	Ligneous	Chenopodi	Scirpus	Chara	Zannichell	RumexBr	RumexSee	***TYPHA	PotamogS	Ceratophy	AlgalBall	Ranuncul	NajasFlex	Salix bract	BetulaBra	BetulaSe	Menyanthe
2																					1	1
3			3			6																2
4	3.6	3.6				0.5																
5																						
6						1															3	4
7																					10	8
8		3				2													6	2	5	3
9						1															3	
10						1																
11						0.5											1				7	1
12															1			2		2	14	1
13						1										1	1				4	1
14		1				1										1				1	6	2
15					1																9	
16												1				1		3			8	
17						2		3										3			8	1
18					1	1															8	1
19				0.5		1														1	1	
20						0.5												2			3	
21																1		3		1	3	
22				0.5											4			2			2	
23															2							
24																2						
25						1								2			2			4		
26																2	1			1		
27	0.5		0.5			0.5					1		2		3	10		2		4	4	
28								2												1	1	
29																	1					
30															2	2				1	2	
31			0.5											1								
32		0.5	0.5			0.5								1		2						
33			0.5										2			2	2			1		
34									2			1	6			1	7					
35							10	5	20	4	3	7	2	8	1	1	10					
36							2	1	20	2	1	2	4		1	4	4					
37							4	2	23	2	6	3	2	2	3	1	6				1	
38							16	1	5	1	14	8	4		4	5	13					
39							6	1	29	4	2	7	2	9	1		25					
40							3	2	63	4	12	14	4	3	1	4	41					
41							3	3	36	5	11	18	2	1	1	2	35					
42			0.5				12	3	62	3	10	9		1	1	2	55					
43							7	3	46	2	9	11	2	1			38				2	
44							7	3	109	3	4	5		1		1	23					
45							10	6	45	4	16	15		3			50				1	
46							3	6	21	2	10	5			5	5	14					

Appendix I
Site 2-2 Macrofossil Data Continued

	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
1	Carex Seed	Grass Seed	Sium sauv	Geum rival	Other seed	Promen ex	Amnicola	Menetus	Physa	Promen ur	Ferrisia	Ostracoda	Statoblas	Cladoceran	DriedMate	Subsample
2	10	1		2	1									1	2.33	4
3	15	1	1	1	1									3	1.97	4.1
4	17				1									12	2.07	4.3
5	23		1												2.09	4
6	2														1.98	17.5**
7															1.65	3.6
8	3				1									49	2.19	3.7
9											0.5			6	2.12	3.7
10															2.04	4.3
11	1													21	2.07	4
12	2				2									18		28**
13				1	1					0.5	0.5		1	23	1.93	4.2
14	2				2							1		19	1.96	3.7
15	2													22	2.04	4.6
16	2	2			1							0.5	1	26	1.98	5.3
17		1											1	34	2.16	4
18	3													11	2.08	4.3
19					1									13	1.86	5.4
20	1													9	1.75	3
21	1				1							1		15	1.82	4.5
22												1	1	4	1.82	5.2
23					1							1		9	1.77	4
24												0.5		2	1.8	3
25													4		1.65	4.6
26	2											1	2	7	1.79	4.2
27	2											1		37	2.04	5.5
28	1											0.5	2	5	2.09	4.2
29												1.5		1	2.2	4.6
30	1											0.5	2	5	2.16	5
31												0.5		4	1.91	4.5
32												2	2	5	2.17	4
33												1.5		3	2.49	4
34	1							0.5	0.5			2.5		6	2.04	5
35	1							1.5	0.5	1.5	5.5			22	2.76	4.6
36	3							0.5		0.5		4	1	44	2.74	4
37	1						0.5	1		1		6		63	3.39	5.3
38	1						0.5	1		1		1.5		78	2.89	4.7
39						0.5	1	0.5		0.5	0.5	2.5		71	3.9	5.4
40						0.5	0.5	0.5		2		5.5		101	4.6	5.4
41	2					0.5	0.5	0.5		1		2		44	4.38	4.8
42	2						0.5	0.5	2	1		0.5		104	3.94	4.5
43	1					0.5	0.5	0.5	1	5		2.5		84	3.65	4.7
44						0.5	0.5			3		1.5		55	4.17	4.5
45	1					2	0.5	1	6	2		2		80	4.29	5.7
46	3									0.5		4		48	5.3	5.1

Appendix I
Site 2-3 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Depth	Mineral	Large Det	Herb mat	Herb root	Carex Lim	Tomenth	Sphagn. S	Sph. CUSP	Myrioph h	Ceratop h	Potamog	Drepan Sp	Drep. Cras	Callier Gig	Calliergon	Drep. Revo	Drep. Poly	Sphagn. W	Drep Adun	Drep Ad. K	Meesia Tri
2	0-5	0.1	20																			
3	15-Oct		25	3	63			1														
4	20-25	0.1	20	13.5	63.8	2																
5	30-35		17.5	12.5	65.4	1.5							0.5									
6	40-45		25	10	64.2	2												2.5	1.5	1		
7	45-50		12.5	10	66																17.5	
8	55-60		25	5	31																	
9	65-70		22.5	5	44	5											17.5					
10	75-80		15	10	25.5	4							1							1		43
11	80-85		7.5	6	65	1.5															12.7	1.6
12	95-100		25	4	49.4															0.1		
13	110-115	0.5	8.5	15	64	1															2.5	
14	120-125	1	17.5	3.5	64.3					1						0.7	0.7				6.1	2.2
15	130-135	1	32.3	6	41	3.5						0.1									10	
16	145-150	0.5	35	1	25							0.1									37	
17	150-155	0.1	63.9		7.5							1.5									22.5	1
18	160-165	0.5	17.5	5	8					1	4	8.5		12.5							24	8
19	170-175	0.1	40		7.5					1	1	24		6.3							16	0.5
20	180-185	0.5	18	1.5	11.5					2		29		10.7	2.7					2.7	16	5.4
21	190-195		64.5		3	0.5						4.5									5.5	1
22	200-205	8	67		4.5					1	1	4.5		1						2	4	3.5
23	210-215	3	87.8								4	5									0.1	
24	220-225	2.5	67.3	2.5	10			1.5		3	2	5		1.5							1.5	1
25	230-235	1	80		7.5				0.5	1	4.2	1		0.5							0.5	
26	240-245		72.5	1	15					2	7.5	1	0.5									
27	250-255	3	91.8		1.7					1	0.5	0.5		0.1							0.2	0.2
28	260-265	1	64		22.5					3	3.5	3		1		0.5				1.5		
29	270-275		89.8							5	2.5	2.5	0.1									
30	280-285	1	83.4		7.5			0.1		2	3.5	1.5		0.4								
31	290-295	0.1	70.5		15					1	10	1.5	0.3	0.3								
32	300-305	1	73.5		15	0.1				2	3	1										
33	310-315	0.5	88.1		1					1	10	0.1	0.1	0.1								
34	320-325	10	75.4		2		0.1			5	5	1										
35	330-335	5	80		5					5	3	1										
36	340-345	2	73.1		15			0.1		3	3	1	0.1	0.1								
37	350-355	7.5	66.5		15						7.5	1	0.7						0.8			
38	360-365	1	86.4		5		0.2	0.2			5		0.2									
39	367-372	17.5	43.7		35.5		0.1			0.1	2	0.5								0.1		
40	377-382	2	72.5		22.5						2											
41	387-392	20	64.2		10			0.1		0.1	5		0.1									
42	400-402	30	57.8		5					0.1	5	1							0.5	0.1		
43	407-412	34.9	5		35					0.1	25											
44	417-422	10	82		5		0.3				2		0.3									
45	427-432	5	89.4		3			0.1														
46	432-437	30	63.8		5						1											
47	447-450	20	74.7		5																	
48	457-462	25	71.9					0.1														
49	462-467	10	64.1		10			0.1			5	0.1	0.1									
50	475-480	5	80		7.5						7.5											

Appendix I
Site 2-3 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
1	Mossla Lo	Drep. Vern	Rhizo pun	Wood	Ligneous	Mychorr	Decid lvs	Zannichell	Cerato See	Chenopod	Salix br	Scirpus	Chara	Blue-g Alg	Rannuc Sd	Typha	Myriop See	Rumex br.	Rumex see	Potamo Se	Najas Flex	Mentha ar
2		8.3	30			40	0.5															
3		1			1	5																
4	1	4			2	3	0.5				1											
5	1.5				1		0.1															
6						2.8	1															
7	1				1	0.5	1.5															
8		0.5			2	32.5	3.5															
9						5	1															
10						0.5																
11		3.2				0.5	2															
12					1.5	20																
13	2	0.5			1	3.5	1.5															
14		0.7				4										1	2	1		1	2	1
15					5	1	0.1					1			1	1			1	1	1	1
16					1								2	4		2				1	10	1
17					3.5								2	3	2	2				2	12	1
18	12												1	18		7				1	2	
19	0.5				5								3	12	1	1	2			1	1	
20				0.5									5	20		2				1		
21					30						1		5	1							2	
22				6	1					1	4		7	5	2	2	2	1		4	3	1
23									2				22	32	2	6	2	1		2	2	1
24				1		1					1		2	23	5	5	3		2	5	1	
25													1	4		7						
26									3			1	8	10	11	5	1	2		1		
27									3	1			2	16	5	6	1	2	2	1		
28						1				3	1	4	10	13	10	14	2	2	1	2	3	2
29												1	32	44	6	5	7		2			
30						0.5				2	1		5	22	11	33	1	7	2	4	7	
31					1.5		0.1			1			6	20	22	26					1	
32					3				2	1	1		13	22	23	12	1	3		2		3
33									10					166	8	4		1	1			
34									1					100	12	7	4			1		
35													1	45	15	29		2	3	3		
36				0.1					1	2				35	26	24		4	3			
37								1	3	1		4	1	24	19	18			3			1
38					1					3			3	37	17	11	1	5	3			1
39									1	2		6	8	24	14	15	1	1	4	1		
40									1	2	2	1	5	23	15	31	1	3	3			4
41									1	2		4	10	23	12	16	2		2			
42										1			2	23	5	13			1			
43										17	1	28	5	10	4	7		8	1			1
44									2	8		13	2	3	7	28		1	4	1		
45								2	1	37	1	30	11	1	30	12		30	13			
46									1	5		1	11	7	13	18		2	4			1
47										6		2	7	16	22	14	1	1	4			
48										4	1	1	38	5	12	17		2	8	1		
49									1	2		8	6	2	6	7				2		1
50									1	9	1		8	12	6	8		2	2			

Appendix I
Site 2-3 Macrofossil Data Continued

	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI
1	Sium scuv	Menyanthe	Betula br	Betula see	Carex seed	Carex bea	Carex peri	Flat gray O	Grass bea	Other See	Ostracods	Cristate m	Cladoceran	Caddisfly	Charcoal	Dried mat	Subsample
2			1	9	1						0.1					1.89	3.5
3		2		4	5	3			11							2.48	3.5
4		4	1	38	6	1			5		0.1			1		2.24	3.2
5				3	4				2	1						2.07	1.7
6			1	3	11				1					1		2.23	4.8
7				3	12		2							2		2.1	4
8		1	2	8	7				6				3		0.5	2.55	3.7
9		17	1	10	22			1	6	1				2		2.17	5
10		23	2	18	3											2.11	5.2
11		25	3	21	22				1					1		2.18	5.2
12	3	9	1	8	14	1			2	1			2	1		2.25	4.2
13	1	4	1	8	11				1	3			3	1		2.86	4.4
14		16	6	17	7			2	1				11			3.12	4
15		6	1	23	7			1	1	6			6			2.90	4.2
16		2	2	10	3								6			2.24	3.8
17		7	1	15	6					2			12			3.11	5
18		6		6	7			1	1	2		1	10			2.93	4.7
19		5		2	9		3		2		0.1	1	22			2.69	4.5
20		1		6	8				1				12				4.5
21		1	2		7						0.5		6		0.5	2.71	4.5
22		2		8	6				1	5			11			2.92	3.2
23			3	5							0.1		22			3.03	4.3
24	1		8	14	3			2		2	0.1	2	20		0.1	4.3	4.9
25			1	5	6					2	0.5	1	10			4.92	2
26	1			10	3			3		6	0.1		79			4.64	4.4
27			2	6	6					1	0.3	2	19			3.43	3.7
28			4	9	9			2		1	1		35		1	4.68	4.1
29			2	7						1	0.1	1	18			4.41	4.3
30			1	4	6	1	1	1	1		0.1	1	66			4.99	4.7
31				1	4		1	1			0.6	1	54			3.1	4
32				1	5		2			2	0.6		49		0.5	5.59	3.8
33					3			1		1	0.1	2	22			2.69	3.7
34					1						1		15		0.5	7.34	3.6
35					8			3			1		33			5.05	3.7
36				2	12		3			2	1		57		0.6	7.68	4.7
37				1	2			6		1	1		62			5.78	5
38					6		1	4			1		83			5.56	5
39					7					2	0.5		68		0.1	6.19	4.2
40					16			5	1	2	0.5		147		0.5	7.13	4.3
41					5						0.5		71		0.1	5.92	3.7
42					1			2		1	0.5		40		0.1	3.87	3
43					16		2	3	1		0.1		135		0.1	4.64	3.6
44					14			5		1	0.5		35			5.4	4
45					4			3		1	2		114		0.5	5.03	3.3
46					5			2		2	0.1		53		0.1	5.78	3.6
47					2			2			0.1		151		0.1	7.02	3.7
48										1	2		165		1	9.27	4.5
49					4			2			0.5		86		0.1	8.19	4
50					6			1		8			123			6.77	3.5

Appendix I
Site 3-3 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Depth	Mineral	Detritus	Herb	Herb root	Myriophy	Ceratoph	Potamo	Drep. Sp.	Drep. Cras	Drep. Adu	Sphag ma	Sphag CUS	Sphag ACU	Sphag Wa	Mychorr r	Picea	Wood	Ligneous	Decid. lvs	Larix need	Chara
2	15-Oct		48	2	10										19	7.5	0.5		10.5	2	0.5	
3	30-35		55	2.5	20										9	2.7	0.1		7.7	2.5		
4	40-45		20		3.5										3.5	10			47.5	8		
5	50-55		45		17.5									7.5			1		8.5			
6	60-65		53.5		7.5								0.5	1		14			22.5			
7	70-75		36.5		1.5									1		7.5		45	7.5			
8	80-85		69.5	5	18							1		1		1.5			4	0.1		
9	91-96		51.5	11	25.5									2		1		1.5	7.5			
10	99-104		66.5	2	23	1			1							3.5			2		1	
11	110-115	3.5	62		22.5	1	1	1		2	1			1					6			
12	120-125	1	64		19.5	1		2.5		1				1					9			3
13	125-130	7	71.5		8.5	1	2	1.5	1					1		1			5.5			
14	135-140	1	77.5		5		1		1					1					12.5			
15	140-145		67.5		7.5		1	1	1					1					20			1
16	155-160	2	71				1	1.5			1			3.5					10			2
17	170-175	5	73		10		1		1					1					2.5			1
18	175-180	60	18		3									2		15	1		8			

Appendix I
Site 3-3 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
1	Chenopod	Scirpus	Typha	Myrioph Se	Rumex br	Rumex see	Potamo Se	Cercis Sed	Blue-g Alg	Ranunc S	Najas Flex	Bidens	Eleocharis	Betula see	Betula br	Menyanthe	Alnus	Carex seed	Carex base	Carex pert	Grass seed	Grass base
2			1											24	7		10	2				
3														73	18		1	9			1	2
4														27	5		2	3	1		3	
5														29	3	2	1	2				1
6														26	5	47	1	8				1
7														4				1				
8														49	7	1	6	30	1	11		1
9												1		22	12	6		7				
10						1								43	10	14	2	10		2		
11					5	1				1				17	6	3	2	15				
12			2	2		1	1		1	11			6	30	9		4	21				
13			2	1		1			7	8			2	30	8		4	11				
14			4			1			1	4			3	151	45		3	14			1	
15			3			3			1	3				96	27		1	14				1
16		1	2						4	2	2			45	22		2	21				
17	1	6	13			3		1	3	7				28	4			6				
18		1	10					1		10			1	3	1			2		1		

Appendix I
Site 3-3 Macrofossil Data Continued

	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD
1	Geum rival	Mentha ar	Salix br	Potentilla	Flat Gray C	Other See	Ostracoda	Cladoceran	Cristatella	Charcoal	Subsample	Dry wt.
2					5						3.8	1.96
3			1					1		0.5	4.4	1.94
4					3	1		1		7.5	3.9	1.81
5					5			1		2	4.4	1.92
6			1	7						1	4.7	2.2
7				1				2		1	4.2	2.08
8	4			1		1		11			4.7	2.24
9					2						4	2.41
10					3	3		7			4.4	2.49
11			2		4			13	1	0.5	4.6	3.17
12		10	1		9	2	1	21	5		4.2	3.39
13		5	1	1	12		1	18	13		4.6	4.07
14		9			32		1	29	9		4.9	2.95
15		1			10	38	1	4	4		3.7	3.39
16			2		0			16	2		4.5	3.53
17		9	2	1	1	5	1	9	1	1.5	5	10.14
18		6					1	3	2	2	4.7	9.47

Appendix I
Site 27-4 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Depth	Mineral	Detritus	Herbaceou	Herb root	S. ACUTIF	Sph. warn	Sph. sub	Sph. teres	Decid. lvs	Oxycoccus	Pleurozium	Callierg st	Ledum lvs	Sph. angu	Sph. mage	Sph. fuscu	Polyt stric	Sph. nemo	Sph russowi	Aulacom p	Mychorr r
2	0-5		31.5															10	13	5.5	12.5	12.5
3	10.0-15		5													17.4	75.6				1	
4	20-25		[illegible]													1.6	76.5	1				16
5	30-35		[illegible]													45.4	45.5	1				
6	40-45		[illegible]		1							1	1	1	66.7	7.3						6.5
7	50-55		6										1	1	52.8	17.6	17.6	1				
8	60-65		10	1						1	1				12	40	28	5				1
9	67-72		22.5		1						1					6.2	56.3	11				
10	75-80		30	2	25	1.7			0.2						5.8	30.8						2.5
11	87-92		38.5	14	3.6				10	1					2.5	12.5						
12	95-100		25	7.5	58.5			0.5	4.5	1						0.5						
13	104-109	30	20		31.4	1.3	1		1						1	4.3						7

Appendix I
Site 27-4 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
1	Ugneous	Picea need	Charcoal	Betula see	Salix br	Flat Grey c	Grass base	Eriophorun	Carex seed	Carex peri	Betula br	unknown	Cladoceran	Ostracoda	Subsample	Dry wt.
2	12.5	1	1.5						1						2	1.52
3		1									1				3.3	1.45
4		1	1												4	1.46
5	1	1	1								1				3.3	1.44
6	5	8	1								16				4.7	
7	1	2									9				3.6	
8	1	1									3	1			4.6	
9	1	1						1	2		2			1	3.5	1.46
10	1		2				10		63			6			4.5	1.57
11	14.5	1.5	1	3	1				12		7				3.67	1.55
12	1	1	1	13	1	1			43	7	30	28			3.5	2.12
13	1		1	1					3		2	1	6		4.2	7.21

Appendix I

Site 35-2 and Site 35-3 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Site 35-2																					
2	Depth	Mineral	Detritus	Herbaceou	Herb root	Sphagnum	Decid Lvs	Potamoge	Sph. mage	Ligneous	Picea need	Larix need	Chara	Potamoge	Scirpus se	Typha see	Al[illegible]	[illegible]ay C	Eleocharis	Rannun Sc	Geum rival	Potentilla
3	Surf		57.7	22.5	19.5					0.1							[illegible]	[illegible]				
4	0-5		70	5	25												[illegible]	[illegible]				
5	10.0-15		45.3	3.6	51						0.1	0.1					[illegible]	[illegible]				
6	20-25		51.3	4.3	44.3												[illegible]	[illegible]				
7	30-35		34.9	5	60						0.1							[illegible]				
8	40-45		72	1.3	26.7											2			1	21		
9	50-55		55	1	44								1			1		4		5		5
10	60-65		67.5	2	30.5											3		4		23		
11	65.5-68	2	60.7	1.3	36											9	8	1		3	1	
12	70-75	0.5	74.2		23.3				0.5	1.5			9			65	3	1	1	47		
13	80-85	1.5	93.5		3.5				0.5	1.5			31		2	63	5	8	2	47		
14	92-97	0.8	96.1		2			0.1		1			27	1		67	4	1	2	12		
15	103-108	0.8	91.8		5.7					1.5			34		2	63	4	3	2	6		1
16	110-115	50	46		4								3	1		12	2			1		
17	120-125	95			5								1									
18	131-136	98		2									1			4				1		
19																						
20	Site 35-3																					
21	Depth	Mineral	Detritus	Herbaceou	Herb root	Sphagnum	Decid Lvs	Potamoge	Sph. mage	Ligneous	Picea need	Larix need	Chara	Potamoge	Scirpus se	Typha see	Algae	Rat Gray C	Eleocharis	Rannun Sc	Geum rival	Potentilla
22	Surf		25	12.5	62.3												1					
23	0-5		35	2.5	8.5		0.5			0.8												
24	10.0-15		42.2		7.3	0.1				50	0.1							1				
25	21-26	27.5	40		7.5					5						17						
26	30-35	50	43		2	0.5				2	0.5					4						
27	40-45	99		1																		

Appendix I

Site 35-2 and Site 35-3 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1																				
2	Mentha ar	Rumex see	Sium sauv	Betula [illegible]	Betula br	Lemna mi	Gramineae (	Grass base	Carex base	Carex peri	Carex seed	Alnus seed	Other seed	Ferrissia	Amnicola	Ostracoda	Cladoceran	Charcoal	Subsample	Dry wt
3							2			7	15					0.2	2		5	1.69
4				1				9	9		5						2		2	1.93
5						0.1		1	3	1	6						9	0.1	3.5	2.35
6	1			2				2	2	4	15						7		3.5	2.34
7			3	11				3	3		42						8		5	2.65
8		1	1	2	2			1			46						46		4.3	2.59
9	7	1		3				1			22		5				14		3.1	2.61
10	2							1	1		37						107		4.5	3.09
11											8		4				28	0.1	3.8	3.59
12	3			1							10		7				209		3.7	3.64
13	3			2							4		17			0.6	176		4.4	3.29
14	1										1		5				109		3.5	3.73
15													4			0.1	91	0.3		3.83
16											1		1				12	1	4	10.53
17																	2		2.3	7.11
18																	2		3	6.03
19																				
20																				
21	Mentha ar	Rumex see	Sium sauv	Betula see	Betula br	Lemna mi	Gramineae (	Grass base	Carex base	Carex peri	Carex seed	Alnus seed	Other seed	Ferrissia	Amnicola	Ostracoda	Cladoceran	Charcoal	Subsample	Dry wt
22			1				14	7	1		1	7	2	0.1	0.1	0.2	5		3.5	1.75
23							3					1					8	51.7		2.16
24												1						0.2	3.9	2.73
25																		20	3.7	6.64
26																		2	3.6	10.76
27																			3.6	5.14

Appendix I
Site 48-3 Macrofossil Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Depth	Mineral	Detritus	Decid. lve	Herb mat.	Herb root	Larix need	Mychorr r	Picea need	Wood	Carex seed	Carex bea	Grass bea	Alnus seed	Betula see	Mentha an	Ranun. S	R. Gray Ca	Eleocharis	Typha	Unknown	Ostracoda
2	0-5		68.9			3		4		23	3	2									2	0.1
3	19.0-14	0.1	30.4		0.5	6		7.5		55.5	2											
4	20-25		32.5		3.5	47.6		15	0.7	0.5	15	1			1							
5	30-35	0.1	42		11.5	27	0.1	19	0.2	0.1	20	1	1		1							0.1
6	40-45		42		5.2	40		10	0.1	2.5	4	2	1	1	2	2						
7	50-55	1	57.4	0.5		38.5		1	1.3		5	1	1			3	3	2				0.1
8	55-60	0.3	43.3			48.9		3	[illegible]		4				1	1	3		3	1		0.1
9	60-65	30	41.8			5		2			1					3	4		4	2		0.1
10	70-75	82.9				5		2								1	2		2			

Appendix I

Site 48-3 Macrofossil Data Continued

	W	X	Y	Z	AA	AB	AC
1	Cladocera	Snails	Promenetu	Cristatella	Amnicola l	Charcoal	Subsampl
2							3
3							4
4							4
5	2						4.2
6	4						4.6
7	6		0.1		0.1	0.1	4.2
8	3	3.3					3.7
9	2	10		1		0.1	3.1
10		0.1					3.7

APPENDIX II

Weighted Means for pH and Height Above Water Table of 1331 Reléves in Western Canada

Species	Mean pH Corrected for Skewness	Mean Height Above Water Table
Sphagnum russowii	4.24	2.8
Sphagnum riparium	4.26	0.5
Sphagnum magellanicum	4.33	2.1
Sphagnum capillifolium	4.37	3.9
Polytrichum strictum	4.58	2.4
Sphagnum angustifolium	4.62	1.7
Pohlia nutans	4.7	1.3
Pleurozium schreberi	4.73	2.8
Pohlia sphagnicola	4.8	2.5
Drepanocladus exannulatus	4.92	0.4
Sphagnum fuscum	4.97	3
Sphagnum teres	4.98	1.5
Dicranum undulatum	5.03	2.3
Sphagnum subsecundum	5.25	1
Sphagnum squarrosum	5.32	1.2
Calliergon richardsonii	5.81	0.7
Calliergon stramineum	5.69	0.7
Aulacomnium palustre	5.7	1.9
Calliergonella cuspidata	5.92	0.5
Meesia longiseta	5.96	- -
Drepanocladus lapponicus	6.05	0.8
Drepanocladus aduncus	6.06	1
Sphagnum warnstorfii	6.11	1.7
Calliergon giganteum	6.2	1.1
Tomenthypnum nitens	6.2	1.5
Bryum pseudotriquetrum	6.22	1
Calliergon trifarium	6.39	0
Drepanocladus vernicosus	6.4	1.1
Scorpidium scoripoides	6.62	-0.1
Meesia triquetra	6.66	0.6
Campylium stellatum	6.67	1.1
Drepanocladus revolvens	6.76	0.8
Brachythecium mildeanum	6.79	1.5
Drepanocladus polycarpus	6.86	1.9

Appendix III
Peat Chemistry - Elk Island National Park

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
2	SITE 2.1	0.00	141	6236.9	2644.7	320.45	3300.9	662.74	10.333	<2.37	<1.73	1.6540	689.93	508.81	43.647	7.0184	1333.8	1410.0	6
3		0.00	141	10003	1098.9	103.31	680.66	3873.8	20.631	12.973	5.5173	5.3039	6020.3	40.762	70.474	10.124	701.17	9994.1	6
4		-5.00	142	9524.6	1331.4	214.07	1064.8	9647	16.317	21.672	10.376	3.796	5895.9	44.130	31.401	12.737	476.76	5568.2	6
5		-5.00	142	9482.1	3724.4	630.31	6963.4	801.43	11.037	<2.31	<1.69	3.2811	1146.8	1373.9	44.052	11.75	1700.6	1560.8	6
6		-10.00	143	7606.7	2618	332.34	3564.5	886.67	13.726	6.6904	<2.62	0.7504	842.45	520.16	38.628	10.443	1650.0	2410.9	6
7		-25.00	144	6953.6	2555.6	207.85	1363.3	1375.3	17.598	5.8281	<1.09	0.7608	771.08	437.94	19.836	5.7524	1224.8	2820.1	6
8		-30.00	145	7670.2	2248.5	233.13	1115	2840.2	16.28	6.7821	4.1195	<0.1972	1588.4	412.09	67.316	3.7014	927.77	1412.6	6
9		-40.00	146	7026.5	2027.2	238.49	1022.9	1129	18.203	4.6349	4.0877	0.4127	1287.2	259.29	76.32	2.0601	927.13	1252.2	6
10		-40.00	146	2203	336.62	63.572	561.59	2253	3.4262	5.3374	3.102	0.8751	1720.9	14.833	15.636	4.7181	148.67	1669.7	6
11		-50.00	147	6636	2259.4	238.02	1040.1	666.08	11.689	<2.69	<2.650	0.2704	1192.2	236.94	84.645	2.1336	876.77	1646.4	6
12		-135.00	148	8536.6	1605.6	186.37	926.06	3333.6	8.2985	<2.3	3.7442	1.0703	3370.1	211.84	57.062	6.2031	921.78	3357.3	6
13		-145.00	149	8407.1	1592.2	155.87	973.20	4276.1	7.319	3.0222	5.3158	0.4868	4065.7	112.60	83.050	7.0262	817.68	3002	6
14		-160.00	150	8026.2	1589.4	170.85	1066	3866.3	7.1724	4.4335	6.013	0.5844	3059.8	138.66	99.96	6.3689	785.4	3261.5	6
15		-165.00	151	10437.2	2049.3	202.67	1404.5	4605.2	10.117	4.6047	7.8138	1.6072	4647	216.60	100.03	10.02	1220.1	3788.6	6
16		-165.00	E726	10365.4	2262.4	273.07	1649.8	6776	20.918	8.1049	9.6932	6.2172	4011.1	243.12	101.79	11.651	1429.8	3985.4	6
17		160-165	152	8857.3	1601.4	130.24	1019.9	4794.9	7.8226	6.433	8.632	0.7809	6549.6	166.15	161.06	10.86	853.47	3767.7	6
18		170-175	153	9284.8	1678.6	140.71	1197	6446.9	8.3402	7.7081	9.023	1.4473	6949.4	191.17	233.38	11.426	880.3	3807.4	6
19		180-185	154	8828.2	1550.5	175.92	1058.4	4789.6	5.4361	9.5898	9.1163	1.6410	6182.4	195.22	190.83	13.049	804.26	3244	2
20		190-195	155	9713.9	1667	139.66	1169.2	6234.9	5.6162	7.3032	8.9981	1.682	6930.3	236.56	208.64	10.738	836.78	3521.7	2
21		200-205	156	10211.1	1781.6	141.02	1100.7	4710.7	9.1201	6.3778	9.4336	1.319	7081.9	245.91	190.86	10.66	894.94	3773.7	2
22		210-215	157	11076.6	1705.7	133.04	1077.8	4941.8	6.9987	8.9371	10.333	1.8188	8714.9	285.32	188.26	12.4	931.82	4660.4	2
23		220-225	158	11881.1	1809.7	175.13	960	4329.6	13.668	6.0473	11.085	1.9686	9965.1	311.64	173.41	14.474	840.8	5022.1	2
24		230-235	159	12906.1	1619.2	140.46	1046.1	4712.4	10.444	6.6744	11.604	2.1866	10031.7	340.38	171.4	13.686	985.44	5670.7	2
25		240-245	160	13444.7	2147.1	173.07	1299.9	5746.1	10.217	2.7367	14.241	2.1088	11202.9	356.13	103.01	14.516	659.12	6774.5	2
26		250-255	161	15146.1	2414	171.74	1435.2	8643.3	8.6527	10.799	14.794	1.8964	13502.3	382.11	80.778	15.72	791.95	9198.9	2
27		260-265	162	14856.5	2457.1	195.21	1587.4	7117.3	7.4143	13.316	15.766	2.5951	14066	380.38	80.072	16.646	737.7	9994.8	2
28		270-275	163	15530.6	2404.8	167.43	1435.1	6519.4	8.172	11.003	14.068	3.2455	13573.9	390.05	71.008	16.459	720.87	10114.4	2
29		280-285	164	16382.4	2406.2	160.02	1437.6	6631.3	10.036	13.74	14.769	3.4462	15376.2	385.53	71.086	16.308	739.31	11261.6	2
30		290-295	165	17227.3	2554.4	155.31	1570.4	7037.1	8.0446	16.633	16.926	3.7745	18464	414.04	80.414	16.617	775.66	13724.7	2
31		300-305	166	22060.6	2367.1	132.1	1246.2	5323	9.4108	12.649	14.710	2.7308	18780.8	474.11	86.670	16.086	871.1	16166.8	2
32		310-315	167	25550.4	2596.6	186.66	950.67	7021.3	13.837	14.71	15.869	6.4560	14663.2	492.3	72.459	18.063	726.25	15307.6	2
33		320-325	168	29817.7	3163.2	198.78	1201.9	8909.6	12.685	16.410	18.671	6.0984	14874.8	511.66	78.499	19.074	796.4	16660	2
34		330-335	169	24296.2	2877.6	186.07	1041.3	6732.5	9.2742	15.959	17.516	5.8109	20195	586.13	87.535	20.171	712.33	16670.6	2
35		340-345	170	28674.1	2872.1	185.92	1030	6605	8.1311	13.434	16.932	5.7201	16426.6	674.26	73.226	19.322	720.65	18038.4	2
36		350-355	171	26931.8	2868.5	174.42	1026.4	7185.5	11.407	14.004	16.533	6.653	17071.1	557.53	78.566	19.205	777.08	16476.8	2
37		360-365	172	37307.6	3063.5	181.61	953.54	6755.6	12.216	13.347	14.759	5.7889	11621.1	580.76	71.587	19.022	774.31	16706	1
38		370-375	173	40440.3	3295.4	203.17	1307.9	7680.1	10.809	14.289	13.68	6.8369	10523.4	567.33	71.404	18.622	780.99	14442.3	1
39		380-385	174	19972.4	2800.6	219.09	1584.3	7900.5	10.913	16.299	13.717	6.1625	12837.3	401.79	67.743	19.619	571.91	12130.6	1
40		390-395	175	13876	2654	218.40	1616.4	7987.4	11.637	16.316	13.078	5.1427	9924	280.06	56.657	19.669	497.09	9257.2	1
41		400-405	E726	14478	2763	315.63	2241.5	9449.9	12.073	15.33	13.471	15.373	10201.3	303.02	71.061	26.616	511.03	10404.5	1
42		410-415	E727	11812.3	2784.3	349.01	2531.4	9806.3	19.243	17.026	15.871	9.5548	13146.3	262.61	74.027	25.883	476.02	10057.8	1
43																			
44	SITE 2.2	SURFACE	176	8811.3	2382.7	205.61	1033.1	781.71	11.42	5.1110	<1.85	4.3212	1610.9	882.35	65.458	12.164	1841	1860.9	6
45		0-5	177	11156.1	2077.6	199.00	47.601	1320	14.648	8.148	2.6303	4.1086	1372.2	217.38	99.679	8.5565	1265	3121	6
46		-10.00	178	9714.7	2138.1	235.65	78.96	1436.4	16.114	8.7165	2.9703	4.1687	1172.1	88.513	75.407	8.8249	1068.1	3806	6
47		20-23	179	8756.2	2167.1	280.05	2.3413	2160	17.129	6.2603	3.9056	3.4463	1500	81.139	111.21	4.5325	1060	2440.6	6
48		45-60	180	8226.4	1813.0	240.62	<1.11	1012	13.924	3.9061	<2.170	17.446	1135.6	106.44	97.287	2.7728	1003.8	2263.7	3
49		145-150	E728	6310.3	1618.9	146.81	362.63	680.62	11.18	8.0438	2.6711	3.4886	446.78	29.048	28.71	40.804	569.78	1354.3	2
50		155-160	181	8141.6	1661.5	156.48	<1.11	2222.6	11.267	<2.08	2.7149	3.2767	1584.4	99.603	62.986	5.7163	864.01	2904.2	2
51		175-180	E729	9921.4	2106.4	320.73	2286.7	10600	17.637	26.663	14.048	4.286	6640.6	130.87	124.96	10.007	654.59	2615.8	2

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
52	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
53		185-190	182	8077.8	1667.3	161.78	1732.7	5732	6.4131	9.5545	9.3735	5.4541	5252.3	148.83	276.17	11.204	815.44	3489.2	2
54		195-200	183	8728.2	1772.3	164.35	876.28	6409.6	9.2581	10.580	10.395	3.0289	7216.6	180.86	240.61	12.89	890.67	3531	2
55		205-210	184	9123.7	1813.6	164.89	781.12	5916.4	10.807	9.9656	10.408	4.1787	7314.9	194.77	250.05	13.613	946.43	3865.7	2
56		215-220	185	9116.5	1833.2	147.38	858.22	5779.5	7.7535	9.6966	11.782	4.95	9891.1	231.28	183.44	12.518	768.49	3711.9	2
57		225-230	186	9643.8	1878.8	155.0	910.58	5894.1	5.4428	10.227	12.867	4.9203	11731.8	288.51	198.83	13.803	855	3970.4	2
58		235-240	187	10403.6	1728.1	124.8	500.76	4513	10.930	7.194	11.06	6.5219	14212.9	316.08	209.34	14.183	1066.9	6061.7	2
59		245-250	188	10519.2	2127.1	157.67	1068.1	6673.7	11.787	13.309	14.497	3.9492	17892.1	452.66	174.59	15.459	2308.4	5268.3	2
60		255-260	189	11806.8	2034.3	172.62	836.49	6711.4	10.702	13.276	14.956	5.4270	19804.6	498.21	155.81	15.421	2250.6	7015.2	2
61		265-270	190	11742.0	2017.2	340.92	867.23	5445.9	15.152	10.608	14.533	4.3796	20356.9	504.35	128.86	16.596	2164.7	8672.4	2
62		275-280	191	12040.9	2021.2	153.01	855.72	5726.1	17.461	9.8981	13.649	4.8801	19887.7	517.33	121.04	16.134	1914.2	7917.8	2
63		285-290	192	12176.8	2034.6	165.03	905.77	5578.7	11.568	10.668	14.548	4.3764	20216.2	631.07	126.61	16.226	2004.3	8480.6	2
64		295-300	193	13101	2212.1	178.28	1395.8	6145	15.195	14.898	16.898	5.7547	20898.8	585.33	126.01	17.084	2273.6	9237.8	2
65		305-310	194	13602.4	2089.1	320.40	1323.4	6466.9	17.604	14.474	16.134	4.6986	20150.8	574.19	112.92	17.321	2094.2	9546.7	2
66		315-320	195	13780.3	2001	140.39	1223.1	5404.3	14.599	15.459	16.454	6.7805	23642.5	707.8	121.59	17.218	2031.2	8028.5	2
67		325-330	196	17110.3	2535.9	188.38	1649.6	8010.6	16.582	16.086	17.872	7.8808	18492.4	492.42	101.35	18.137	983.1	9850.6	2
68		335-340	197	10321.9	2115.3	194.68	1574.3	6675.6	5.9289	14.786	13.838	5.42	11199.6	269.69	181.17	14.948	858.37	4267.3	2
69		335-340RE	E730	16043.8	2284.7	289.02	1590.8	7008.7	12.926	17.039	14.019	6.323	21873.9	433.02	74.769	16.501	915	13870.8	2
70		345-350	198	19081.8	2340.9	520.41	1804.6	6080.8	9.0075	15.757	18.609	5.2944	25022.1	469.83	77.169	18.042	951.39	16595.6	2
71		355-360	199	31265.1	2656.8	475.04	1811.6	7050.4	12.020	16.264	17.982	5.8604	21650	496.45	73.695	17.651	901.67	18378	2
72		365-370	200	42528	3307.8	190.53	1602	8326.2	18.214	17.723	19.863	6.0785	18587.9	508.74	78.538	18.281	897.32	17028.6	2
73		375-380	201	47187.6	2864.5	203.19	1306.2	5920.2	16.65	14.246	17.028	7.3977	21328.6	628.13	86.039	19.71	1243.2	19047.3	2
74		385-390	202	31391.1	2836	194.76	1551.5	6767.7	10.521	16.79	19.758	8.5068	21949.8	717.33	88.511	19.852	981.79	17742.1	2
75		395-400	203	26856.9	2113.3	131.12	1068.9	4914	10.851	12.722	12.412	4.6314	15492.1	447.92	61.711	12.993	678.26	13936.8	2
76		405-410	204	27639	2254.5	131.64	1082.6	4744.6	11.63	12.857	14.494	5.294	10813.4	570.08	72.722	16.168	791.61	16934.2	2
77		415-420	205	32246.7	3334.3	239.48	2133.4	6425.3	13.358	18.002	18.075	6.5483	16677.7	538.83	90.861	19.264	797.04	14865	2
78		425-430	206	47098.2	3644.5	232.64	1781.2	6459	15.146	17.027	17.492	6.6538	12786.4	682.55	80.374	19.666	913.53	16957.5	1
79		435-440	207	60410.4	3573.1	241.31	1872.3	8116	13.039	16.238	16.136	7.6306	12010.9	676.33	88.363	18.872	947.67	14798.9	1
80		445-450	208	56040.5	3910.3	262.92	2104.3	6777.2	13.176	16.251	15.887	8.5692	11321.1	731.62	92.605	20.706	940.92	15245.7	1
81		455-460	209	59347.9	4100.2	242.22	2079.1	6917	7.8617	18.619	16.594	9.2097	11176.3	762	93.265	20.367	885.04	12614.9	1
82		465-470	210	66178	4256.7	255.22	2221.8	9742.5	15.288	17.458	18.199	9.2323	11841.5	789.73	89.790	21.805	919.37	12523.5	1
83		475-480	211	61997.8	4296.4	321.26	2315.2	10005.7	13.908	17.446	17.355	10.1	11407.6	784.16	98.542	22.018	900.43	12278.4	1
84		485-490	212	50707.2	4342.5	314.47	2313.9	9805.6	10.871	18.861	17.711	9.1696	11285.8	785.96	93.861	22.51	897.79	13077.2	1
85		495-500	213	47057.6	4465.1	325.86	2532.1	10578.4	12.926	20.76	18.35	9.4081	11790.7	730.92	96.781	22.65	912.4	13004	1
86		505-510	214	27042.3	4130.4	376.2	2448.4	10097.3	15.404	20.061	17.806	11.137	12230.4	580.78	112.84	23.968	828.93	12008.2	1
87		505-510RE	E731	23026.3	4012.8	478.12	2626.9	11613.6	21.601	20.304	17.62	10.03	11611.3	532.03	106.27	21.637	804.46	11869.7	1
88		515-520	215	23677.1	3772.3	460.4	2201.8	9231.1	11.4	17.772	15.736	8.5083	10655.8	549.2	121.3	22.926	772.13	10934.6	1
89		515-520RE	E732	19211.8	3831.5	681.8	2540.6	11677.6	20.193	18.511	17.497	9.5331	11210.4	507.94	117.32	22.358	747.46	11680.9	1
90		525-530	216	14939.2	3181.1	765.82	2242.3	8876.3	31.981	15.661	14.331	8.1782	9388.6	450.83	74.122	19.864	634.89	10445.9	1
91		535-540	217	36703.5	3923.8	673.16	2069	8972.9	23.256	19.104	17.661	12.701	14383.6	531.48	98.131	22.336	808	13686.3	1
92		540-545	218	42522.8	3434.3	678.09	1546.9	7353.7	26.775	16.067	16.198	12.324	13149.6	527.03	81.64	20.296	791.08	10647.4	1
93		545-550	219	70011.3	4535.9	307.75	1915.6	8205.7	19.057	18.941	19.266	13.876	11623.6	701.63	119.13	23.696	986.25	14900.6	1
94																			
95	SITE 2.3	0-5	E733	16482.9	3230.8	232.17	631.95	2222.2	17.347	7.3331	4.0434	3.2698	2055.4	237.05	97.851	4.8584	1445.8	3763.4	6
96		-10.00	E734	15334.7	3063.3	214.55	224.73	667.07	11.528	<2.250	<1.64	1.4118	617.81	11.182	18.228	<1.09	1140.1	2309.7	6
97		20-25	E735	11783.3	2521.5	181.85	185.31	488.03	8.2961	<2.46	<1.70	3.687	853.1	13.319	50.807	<1.18	789.5	1892.8	6
98		30-35	E736	12074.8	2513.4	142.47	146.05	434.99	9.6502	<2.26	<1.64	2.0342	1147.2	8.2403	13.031	<1.09	705.01	2214.2	6
99		40-45	E737	12317.6	2246.2	119.06	102.65	490.3	6.5932	<2.3	<1.07	2.1873	1841.4	10.887	31.181	<1.11	695.2	2880.6	6
100		50-55	E738	15581.8	2846.2	130.89	164.09	568.39	9.3437	<2.23	<1.32	4.1417	2210.8	15.09	40.801	1.5873	723.87	4504.6	6
101		65-70	E739	10227	1916.4	125.27	164.02	508.26	8.4762	<2.25	<1.64	3.5243	2112.4	15.006	18.302	<1.09	611.56	2005.9	6
102		80-85	E740	10928.5	1872.4	142.29	271.87	1696.7	15.327	<2.92	<2.130	2.6316	2766.1	37.47	13.938	2.0187	747.36	2040.8	6

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
103	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
104		88-92	E469	8838	2167.8	259.44	1686	9399.6	28.247	11.107	11.488	5.6025	4700.6	45.887	14.716	8.3071	433.82	1659.1	5
105		100-104	E470	12016.6	1926	162.48	671.71	2771.6	18.008	2.7633	8.4015	4.0816	3720.7	63.447	10.437	8.1240	824.15	2344.1	6
106		120-125	E471	9186.7	2203.3	248.2	1680.1	8541.7	23.478	9.687	11.291	5.904	5720.8	92.497	40.756	13.153	458.16	1691.2	6
107		140-145	E472	8435.2	2004.8	220.65	1336.5	6411	34.838	5.0055	9.6470	7.3171	6339.8	105.6	33.204	14.625	483.04	1737.2	2
108		160-165	E473	8435.9	2031.7	235.91	1610.7	8123.6	24.034	8.6718	10.768	7.1777	5879.3	116.4	53.88	11.727	429.66	2149.2	2
109		180-185	E474	8808.1	2138.5	231.27	1672.6	8284.3	65.992	12.538	11.73	6.1071	6620.9	126.9	56.71	14.936	623.1	2555.4	2
110		200-205	E475	6653	1726.3	214.62	1444.6	6463.1	21.356	6.7357	9.6024	4.6536	6397.1	102.67	63.676	12.317	380.73	2407.7	2
111		200-205RED	E741	6018.3	1595.6	231.64	2714.6	6439.7	18.743	6.4163	7.3469	4.1803	6107.2	101.1	47.693	10.776	396.77	3128.7	2
112		220-225	E476	10676.8	2754.1	328.57	2318	10381.1	30.857	11.958	16.059	8.4748	11305	175.55	59.66	16.893	610.64	6056.4	2
113		241-244	E477	8560.3	2683.4	356.13	2692.3	11780.3	19.295	15.498	16.349	7.0118	9432.6	129.39	61.074	20.384	416.2	3468.3	1
114		241-244RED	E742	5528.6	2458.9	354.33	2680.1	11083.7	13.195	15.295	12.388	6.0458	8125	118.41	49.5	16.893	420.13	3321.2	1
115		260-265	E478	9311	2821.9	355.76	2535.6	11703.6	39.370	14.80	16.908	8.6492	9583.1	167.11	55.428	19.603	453.48	4808.1	1
116		280-285	E479	13868.2	3140.7	358.86	2491.7	11114.3	35.563	10.793	17.295	7.1763	12890.5	244.7	62.998	19.388	610.95	9734.2	1
117		300-305	E480	10614	2818.3	309.48	2395.1	9884.4	24.974	12.926	15.95	8.5294	11088.8	192.04	55.497	18.532	453.77	7657.7	1
118		320-325	E481	12053.1	4459.3	308.55	2732.4	11833.7	17.25	18.825	16.829	5.3034	7828.8	199.55	61.389	19.615	508.85	6472.9	1
119		337-342	E482	11876	3064.1	335.54	2401.6	9423.9	39.672	13.647	15.356	7.404	10519.4	214.09	98.417	16.138	479.08	8805.6	1
120		355-360	E743	16496.3	3105	317.48	2486.8	9769.6	31.688	13.109	14.064	5.6836	12857.3	290.85	59.733	16.636	618.08	10448.7	1
121		377-382	E744	6780.6	2108.2	302.62	2396.5	9972.3	35.741	14.103	11.63	5.8155	8491	143.1	36.107	12.373	331.4	4022.7	1
122		395-400	E745	6280.1	1711.8	229.61	1930.7	7514.1	8.7008	10.858	10.244	3.2847	6486.2	112.03	24.918	9.0612	249.08	3394.3	1
123		417-422	E483	10566.6	3130.8	413.14	2924.6	11844.9	30.689	17.742	18.752	7.0904	9857.4	181.99	85.039	22.286	467.24	6753.3	1
124		437-442	E484	9022.5	2710.8	324.91	2481.5	10064.9	28.27	13.653	15.097	6.4704	7661.3	149.26	60.210	18.469	370.33	5713.4	1
125		457-462	E485	9354.6	2836.9	371.72	2739	10548.5	39.457	18.949	15.977	6.0574	8708.3	158.01	59.248	18.22	424.6	6787.5	1
126		467-472	E486	7870.6	2885.7	407.64	2934.6	11610	25.238	18.65	16.862	8.11	9801.8	134.7	65.295	21.130	387.27	4676.7	1
127																			
128																			
129	SITE 3-1	0-5	E746	4159.9	1026.8	173.58	1213.8	1204.1	14.638	7.3044	<1.28	3.6560	971.46	83.617	28.006	4.4674	1268.5	1346.3	6
130		20-25	E707	5248.3	11120	123.72	1188.6	937.36	14.46	15.749	4.3883	3.2373	1027.7	40.862	37.101	6.0631	1419.6	1583.1	6
131		35-40	E487	6900.6	1261.5	77.108	491.81	1567.1	10.613	2.5996	3.3219	0.6591	1427.4	25.618	20.43	1.8546	931.18	1989.2	2
132		90-100	E488	9039.7	1791.3	148.18	1202.8	4924.4	15.948	6.82	8.0199	3.1028	4952.8	207.7	92.142	10.717	915.23	4586.5	2
133		115-120	E708	10847.5	2046.3	137.73	1302.8	6826.6	20.782	18.27	14.643	6.2052	8007.0	316.38	89.538	17.207	804.09	6501.4	2
134		135-140	E709	11378.3	2083	140.74	1382.1	6089.5	24.331	17.027	13.591	5.6135	10806.4	384.82	97.54	186.47	840.64	7442.7	2
135		155-160	E710	12287.5	2159.1	154.06	1547.6	6473.3	12.376	18.881	16.042	4.2138	13465.6	432.27	96.622	19.261	866.32	9218.6	2
136		175-180	E711	12086	2243.6	164.58	1693.0	7183.7	12.237	18.729	18.835	4.3018	12926.4	448.66	73.67	21.06	851.75	8488	2
137		195-200	E712	10560	2820.6	224.85	2282.5	10199.5	10.611	27.735	20.459	5.8423	14256.2	370.05	69.268	22.016	878.17	7184.8	2
138		215-220	E713	11831.6	2466.4	224.74	1974	8519.3	18.486	21.411	20.872	5.9208	15074.0	381.05	77.599	22.974	700.1	9109.9	2
139		235-240	E714	13493.5	2822.9	238.52	2181.9	9227.7	24.387	23.035	24.435	4.8864	16420.9	418	78.459	23.941	811.77	9506.6	2
140		255-260	E715	17068.2	3151.7	278.36	2214.3	8461.3	31.027	26.444	23.675	5.996	20282.8	463.94	74.088	24.28	785.41	12923.8	2
141		275-280	E716	33108.9	3419.2	276.9	1942.7	9237.8	41.709	23.174	23.25	7.5758	20910.8	498.32	75.288	23.888	832.41	18451	2
142		295-300	E717	47870	3737.5	215.06	1855.4	9468.7	21.42	24.612	25.08	6.8128	24000	611.1	103.32	25.96	908.04	19302.6	2
143		316-320	E718	21441.3	3561.7	280.44	2203.9	10848.2	25.025	25.98	24.464	6.9155	18825.8	481.0	78.902	24.724	788.76	16006.5	2
144		316-320RE	E747	18801.7	3289.3	310.94	2229.8	11288.6	15.441	24.945	19.466	6.5888	17065.2	440.46	88.891	21.493	686.88	14300.3	2
145		342-347	E719	37650.4	3834.6	262.26	1836.5	9576.7	34.478	24.181	24.738	7.6622	21587.2	503.46	78.608	24.913	845.46	16665.6	2
146		355-360	E720	69331.6	4580	315.7	2112.2	11023.3	36.762	25.837	28.041	6.8043	19672	633.4	75.843	26.316	896.94	17477.3	2
147		375-380	E721	127311.1	4450.1	298.99	1514.2	8390.3	35.088	23.017	25.331	12.429	12118.4	1044.5	75.168	22.729	1147.4	18262.4	2
148		395-400	E722	81285.8	4771.3	286.02	1812.6	10068.1	68.281	24.188	24.287	11.233	13109.5	864.83	92.516	23.984	939.82	18106.7	1
149		415-420	E723	108538.8	5551.6	285.42	1581.8	8659.6	46.217	23.981	24.464	10.270	10159.9	1143.3	67.184	24.311	1020.7	17584.4	1
150		435-440	E724	75408.2	6002.1	304.81	1963.8	8969	41.876	23.431	22.376	10.299	10764.4	800.25	93.014	24.389	1032.8	16718.9	1
151		455-460	E725	11871	3548.2	387.1	2670.3	11037.6	25.309	25.646	18.016	7.2305	8751.4	191.42	74.063	23.418	669.75	7425.1	1
152		470-475	E748	9058.7	2904.7	416.96	2302.2	10469.1	23.879	17.649	12.534	6.0681	6891.4	146.16	62.491	17.506	471.1	6404.4	1
153		490-495	E749	11004.8	3107.6	823.47	2583.5	12071.7	39.701	20.72	15.858	7.7651	7458.9	145.88	66.910	18.221	560.96	7026.7	1

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
154	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
155	SITE 3.2	0-5	E489	7641.4	2288.6	488.33	8581.1	802.97	14.64	<2.4	<1.76	4.8892	1657.6	1381	41.701	12.038	2733	1893	
156		-10.00	E562	8393.9	1511.3	408.38	2908.8	762.45	12.837	<2.210	<1.81	7.834	1035.5	657.62	23.599	8.2670	2072.4	1838	
157		20-22	E490	7666.7	1768	140.93	866.87	1607.1	21.111	4.7273	5.2366	4.0242	1666.8	339.49	27.911	6.1492	1449.1	2031.3	
158		30-35	E491	12618.2	1842.2	124.96	276.87	1207.4	10.148	<2.200	6.2716	3.1609	2344.4	121.64	3.4048	3.6048	1185.8	1083.4	
159		30-35REDO	E760	12394.5	2045	104.96	249.94	1038.8	15.886	3.9516	3.0788	2.3846	3134.3	102.09	6.8395	3.4081	872.3	2920	
160		40-45	E492	9907.3	1593.3	161.85	613.96	464.11	9.0598	<2.22	2.746	3.0847	2207.8	67.004	21.999	3.6887	900.3	1449.1	
161		50-55	E493	10014	1801.6	86.382	233.38	657.44	10.488	6.6909	3.9846	1.5227	2494.2	100.58	5.816	88.514	761.59	1919.9	
162		70-75	E494	13056.5	1890.9	66.926	175.56	639.56	10.709	4.4945	4.1143	1.8857	2323.1	71.537	0.6177	2.4587	674.24	3104.6	
163		90-95	E495	11626.3	1653.2	46.083	76.271	363.53	6.8039	<2.420	4.1092	1.0688	2470.9	60.895	<0.2314	3.1888	646.01	2436.6	
164		110-115	E496	11800.4	1489.9	95.349	120.92	487.13	7.8427	55.495	4.7752	1.4840	3461.9	132.22	<0.2198	4.0591	449.42	3968.2	
165		130-135	E497	10642.3	2540.4	284.71	2111.4	11478.8	34.103	8.5693	18	5.4802	7469.4	178.04	62.796	17.570	740.08	4846.1	
166		150-155	E498	7724.5	1893.8	148.92	1699.3	7894.5	14.396	10.593	11.469	3.6041	6012.3	148.98	34.283	11.836	480.7	2880.9	
167		150-155RE	E751	7331.6	1907.3	210.64	1730.3	8570.8	10.376	14.312	13.035	4.0893	5938.8	149.33	37.301	12.884	474.87	3284.2	
168		160-165	E563	9830.5	2232	342.3	1953.1	8848.9	11.887	3.4782	12.142	5.8139	7560.7	189.99	30.237	15.068	824.38	4340	
169		160-165RE	E752	9074.9	2124.3	220.18	1832.2	8305	13.937	10.887	14 612	4.4409	7168 3	193.88	43.434	15.082	872.28	4145.7	
170		170-175	E753	9920.3	1921.8	163.61	1410.7	7880.6	22.234	18.283	13.699	4.6252	7813.1	219.15	45.822	14.843	763.28	5342.4	
171		190-195	E754	11978.2	2555.3	240.39	2148.4	11357.6	32.904	20.894	18.837	7.2999	12432	265.82	60.453	13.267	887.96	7880.5	
172		210-215	E499	12134.6	2728.4	268	2347	11166.6	37.011	10.54	18.036	5.9898	13212.4	250.12	59.187	18.926	804.14	7890.9	
173		230-235	E564	16524.2	2563.6	331.47	1928.7	8216.8	15.687	4.7483	14.061	6.3626	17263.2	321.2	49.646	18.257	619.07	12244.9	
174		250-255	E565	17249.3	2827.1	380.81	1834.3	8292.7	10.36	8.3871	14.089	5.2812	15459.8	308.13	56.063	18.281	882.13	12582.8	
175		270-275	E566	34961.8	3256.3	286.14	1890	9286.2	14.124	8.9006	16.581	7.0666	14784.6	334.93	62.391	20.189	693.28	13206.2	
176		292-295	E755	6167.3	2139.6	282.27	2428.1	9494	9.7428	15.749	13.167	3.7493	7601.4	86.335	36.959	16.747	304.86	2490.4	
177		295-300	E567	23510	3043.2	340.59	2377.9	9098	11.843	4.1773	13.864	7.2893	8319.3	210.24	26.513	16.92	425.86	2374.3	
178		320-330	E756	26644	5076.4	388.92	2879.9	12945.5	12.181	21.250	18.245	5.8181	9926.8	395.04	42.082	21.989	412.18	1287.6	
179																			
180	SITE 3.3	SURFACE	E500	20120.1	3169.6	220.13	1762.6	2635.4	47.858	5.0086	4.8016	10.767	2491.4	604.59	196.86	14.477	1868.6	2640.4	6
181		-10.00	E501	22726.4	3401.8	113.85	272.8	944.46	19.068	<2.290	3.8985	2.3801	1794.3	149.51	30.732	4.3594	748.71	3033.1	6
182		20-25	E502	21611.3	2641.6	101.28	228.75	1297.9	24.127	<2.260	3.4270	5.3056	3223.2	85.681	47.312	6.4478	816.18	2664.4	5
183		30-35	E503	30360.8	2998	95.063	149.24	1129.0	21.444	<2.280	5.7346	4.9834	6798.9	129.23	57.451	5.8916	765.08	2351.6	6
184		40-45	E504	34603.5	3087	130.24	172.2	739.76	13.156	<2.250	6.183	6.111	12086.8	209.6	59.992	8.0723	683.03	3218.4	5
185		50-55	E505	26622.4	2702.6	103.66	176.02	1400.4	26.561	<2.270	4.9401	5.6677	9610.6	184.03	23.66	6.9113	588.43	3093.1	5
186		70-75	E506	27976.4	2779.8	84.714	351.41	3650.0	49.009	<2.280	7.8686	6.4384	10827.6	185.37	61.434	9.1568	696.37	3612.1	5
187		91-96	E507	21221	2366.7	115.61	317.61	2651.2	41.213	<2.27	5.7473	6.9729	10030.3	155.1	91.307	11.46	611.32	3134.6	4
188		110-115	E508	12640.6	2621.4	236.59	1767.7	10464.5	95.703	6.324	14.676	6.0604	9370.1	109.8	56.653	11.974	508.24	2601.6	4
189		130-135	E509	13202.5	2297.1	158.93	1133.3	7517.4	101.8	<2.28	19.827	4.3893	9201.8	108.28	106.12	11.506	457.56	4180.9	4
190		145-150	E510	12535.7	2369.6	197.5	3368.1	9228	100.94	4.9011	23.002	6.6368	10130.7	101.05	123.17	15.807	522.36	4694.5	4
191		165-170	E511	5617.2	1860.6	216.81	1622.7	6794.9	<0.1450	<2.28	6.7598	4.3286	20.356	61.694	35.816	16.841	<2.690	1047.3	4
192		175-180	E512	4976.1	1652.5	163.26	1423.1	6951.5	84.287	<2.28	18.187	5.148	6490.5	55.52	38.856	30.831	230.56	1770.3	4
193																			
194	SITE 22-1	0-12.7	E467	2527.5	695.12	139.26	2334.5	615.96	8.0815	<2.250	<1.550	1.7581	764.83	570.34	48.730	10.48	742.92	1066.6	8
195		20.3-22.9	E151	5419.4	723.1	114.05	556.05	2693.7	11.852	23.611	4.2196	3.6936	1666.1	96.046	73.179	16.578	697.96	1236.2	8
196		33-35.6	E155	4417.2	760.55	78.808	240.18	559.9	10.173	11.352	<1.950	4.1012	694.03	46.958	34.643	4.2580	345.58	1001.6	8
197		41.90	E156	4046.2	728.63	59.273	226.64	939.56	16.736	10.073	2.8993	2.476	1088.1	33.531	26.634	3.0105	439.64	1003.3	8
198		55.9-58.4	E157	6672.1	668.09	81.054	356.41	719.43	11.267	18.881	1.8082	3.0182	866.03	44.78	30.139	4.1348	402.12	1027.1	8
199		72.4-73.7	E150	5331.2	382.5	115.46	292.51	1498.5	13.072	17.842	<1.550	4.6628	1302.1	9.2738	23.118	9.6195	527.59	2631.9	7
200		83.8-88.9	E147	13534.3	617.53	60.744	165.26	1188.6	18.252	12.27	<1.710	4.409	1609.1	14.38	7.189	4.2078	287.87	3718.7	7
201		101.6-106.7	E148	16228.1	637.27	58.61	140.43	998.13	16.127	7.9707	<1.560	4.6139	1980.8	35.028	22.588	6.9267	417.46	9048.3	7
202		118-122	E795	2007.8	2689.1	366.77	2780.5	15303.7	19.507	27.835	18.745	9.6387	19861.7	194.09	72.893	33.16	622.88	1021.3	7
203		124.5-129.5	E152	20437.7	916.62	137.42	301.73	1289.9	15.566	9.0772	3.2634	6.0324	3693.7	63.783	28.318	17.126	519.82	12800.1	1
204		142.2-147.3	E154	12179.8	1407.4	259.02	2409.1	9649.4	16.184	22.322	13.892	4.1249	5504.5	37.161	55.67	17.668	625.11	7649.7	1

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
205	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
206		162.6-167.6	E488	12272.6	2341.3	346.22	3465.8	13384	16.283	14.292	19.795	6.4801	16391	186.99	99.442	21.358	662.09	9198.9	1
207		182.8-188	E153	17385.5	1406.6	200.72	1750.8	5766.1	17.438	18.215	11.118	6.6522	9308.9	188.55	75.864	16.889	810.18	12946.8	1
208		201.9-204.4	E149	12751.1	1536.3	241.1	2552.1	7448.6	7.0833	22.571	12.821	6.1642	14341.6	148.64	110.35	24.425	631.83	10330	1
209																			
210	SITE 22-2	12.00	E140	5426.9	853.88	110.15	1213.5	851.9	12.582	18.521	<2.820	5.372	1304.9	95.048	52.778	6.8502	726.84	1125.4	
211		16.50	E137	6021.3	745.17	70.278	463.67	993.72	13.28	13.346	<1.600	6.0295	1134.4	46.499	30.746	3.6284	672.8	1264.4	
212		25.40	E143	4851.5	885.15	70.635	452.89	1235.7	16.78	14.368	<1.730	3.7802	1113.1	43.66	27.042	4.0545	661.28	1128.5	7
213		31.80	E144	4470.4	656.81	101.47	394.15	1176.1	13.67	11.47	<1.830	4.3588	530.18	11.126	25.218	6.2987	504.18	1997.8	7
214		40.60	E138	7848.3	631.88	50.006	201.71	511.69	9.3986	6.3484	<1.480	2.9081	632.65	7.1739	20.883	3.0532	394.02	1995.8	7
215		61.00	E139	9201.6	641.06	42.415	165.73	435.12	7.628	6.7503	<1.600	2.321	1320.5	8.1873	17.49	2.0825	372.58	2388.7	7
216		81.3-88.4	E145	11933.5	798.08	107.56	820.83	4298.5	17.931	12.662	5.9898	4.9811	3888.2	16.198	39.487	8.4824	734.88	7788	7
217		101.6-106.7	E799	16823.6	1122.2	163.36	831.95	4601	15.898	4.7223	8.097	6.1328	9338	42.159	72.242	<1.07	741.63	11234.7	2
218		116.8-121.9	E800	10005.2	1564.1	308.41	2137	12412.7	18.727	15.769	13.325	4.9998	6889.4	60.837	38.088	<1.05	528.84	6678.5	2
219		137.2-142.2	E801	9119.2	1861.1	382.34	2852.3	19632	18.781	18.324	17.832	6.528	8283.1	64.438	66.718	<1.38	824.84	6880.2	2
220		160-165.1	E802	3880.2	1953.6	419.8	3005	14406.9	13.729	20.178	18.017	14.258	8321.3	52.548	74.877	<0.7471	541.99	1587.9	1
221		185-190.5	E803	2329	1791.6	375.77	2741.5	11178.5	11.431	18.354	15.027	5.4527	7222.8	45.849	37.011	<0.98	284.28	909.55	1
222		200.7-205.7	E804	1682	1767.2	364.4	2938.6	11121.6	20.844	14.01	12.927	2.3749	8163.4	41.089	34.124	<0.7454	178.44	414.58	1
223		221-226	E805	3355.5	2700.9	509 24	3764.8	15701.8	17.284	22.102	19.797	4.5006	9409.5	70.552	49.538	<0.7914	263.42	1419.8	1
224																			
225	SITE 22-3	0.00	E133	10728.8	1210.8	294.87	707.86	1617.5	12.819	10.992	<1.850	8.2452	1579.4	226.27	212.83	13.322	1178.8	4093.2	3
226		12.70	E464	8849.8	1279.9	251.16	4858.1	1012.9	12.66	<2.28	<1.66	3.6133	1442.9	247.04	105.45	9.1418	1817.4	3785.4	4
227		24.10	E134	16582.2	1731.6	310.62	1189.8	3612	17.488	18.624	4.3632	10.034	2898.7	179.04	187.05	12.328	1452.7	5061.8	4
228		27.90	E136	16987.3	1784.1	203.61	305.02	2891.4	17.875	19.542	4.1118	10.057	3020.5	332.81	282.67	11.909	.1430.5	6164.4	4
229		41.90	E465	33456.1	2414.7	390.03	672.64	1369.6	22.195	<1.840	3.6122	22.093	3236.1	28.269	191.58	10.309	1659.7	12605.3	4
230		45.70	E129	18281.1	1605.6	175.63	368.07	998.74	13.857	10.459	2.5118	10.454	2350.1	163.61	177.88	5.9403	1078.8	8527.8	4
231		60.80	E131	23487.5	1600.9	116.29	1073.7	883.49	12.09	8.7191	1.8724	9.4574	3727.5	78.934	174.12	4.7418	959.17	11872.6	4
232		71.10	E130	22137	1569.9	160.85	691.46	4787.4	18.441	11.388	6.5748	7.6249	4060.6	19.016	127.56	12.831	1030.5	11132.3	2
233		81.3-91.4	E135	18241.2	1626.5	164.54	903.03	7607.6	9.7744	17.268	10.988	6.577	6593	51.191	94.632	16.67	828.1	8849.3	2
234		101.6-107.2	E132	9028.7	1526.2	240.79	2067.8	11577.2	14.661	22.502	15.552	3.5011	7359.2	88.782	67.411	22.627	364.34	3107.2	2
235		116.1-121.9	E466	26584.7	6066.5	1163	7540.5	41727.6	66.462	59.408	53.642	27.589	20764.1	626.46	206.28	108.84	[illegible]	3350.3	1
236		129.5-137.2	E128	54073.4	3886.5	318.99	2301.7	9538.1	7.1887	22.017	12.476	6.8861	8762.7	407.1	39.814	21.076	600.66	650.63	1
237																			
238	SITE 27.1	0-5	E687	3389.8	830.4	105.88	2939.3	623.87	11.034	3.9308	<1.920	6.1383	692.7	558.59	59.04	13.899	630.85	648.28	8
239		-10.00	E688	2020.2	616.38	44.405	870.64	628.52	8.0214	3.166	<1.760	2.1233	662.98	203.24	38.107	8.4537	371.18	318.38	8
240		20-25	E689	2836.9	648.64	72.41	938.24	2428.9	9.1556	10.624	4.5847	3.4733	3115.6	41.82	40.850	8.2028	718.40	648.02	8
241		30-35	E690	3103.4	661.54	41.661	492.55	1057.7	11.807	6.4238	1.954	1.5807	1391.6	11.423	30.783	3.237	530.4	635.61	7
242		40-45	E691	3183.8	660.08	54.554	433.09	728.27	13.423	<2.27	<1.66	1.3165	892.82	8.7188	23.743	<1.1	569.98	493.31	7
243		55-60	E692	3428.5	566.5	32.796	83.787	450.94	5.6223	<2.090	<1.53	1.3718	572.09	16.605	18.061	<1.01	238.52	421.02	7
244		70-75	E693	3340.4	452.49	40.287	111.18	660.61	12.013	6.211	2.4862	2.4279	861.78	28.288	12.014	2.3383	330.66	498.61	7
245		80-84	E694	4842.1	498.74	48.568	133.44	562.89	12.626	6.0561	3.1681	2.767	1187.7	29.861	18.879	3.0681	287.36	592.43	7
246		110-115	E695	6017.6	632.83	39.525	86.807	821.07	16.818	6.2891	3.3275	2.2082	1373.2	66.372	16.099	2.0751	224.89	559.03	7
247		130-135	E696	4734.5	560.02	50.704	173.07	1284.6	26.311	5.4669	3.2223	5.881	1410.6	61.098	14.244	2.3857	418.5	816.96	7
248		145-150	E697	5248.5	614.87	38.253	117.13	1048.1	22.078	6.2443	3.4942	2.5807	1887.8	78.099	13.128	2.7763	362.55	896.15	7
249		165-170	E698	6645.1	620.53	49.596	116.22	442.12	8.9378	5.7677	2.5265	3.2081	2235.8	138.48	18.048	2.4465	186.18	611.71	7
250		187-189	E699	5006.4	607.89	36.465	102.24	633.39	14.628	5.3026	3.0007	2.7482	2018.3	116.52	12.786	4.3545	329.78	1061.5	7
251		198-200	E700	4630.8	573.9	42.064	108.06	475.22	10.007	4.3541	2.8784	2.6175	2008.7	128.68	18.404	2.9641	522.66	960.29	7
252		215-220	E701	5541.6	827.48	35.29	118.92	487.93	7.8281	5.5718	3.5085	2.4005	3386.7	176.37	19.705	5.4905	487.52	1318.4	6
253		235-240	E702	6989.1	2447.5	276.24	3220.5	14261.1	18.479	32.604	26.17	8.654	11203.7	314.79	79.520	28.818	606.4	2054.6	1
254		250-255	E703	6046.1	3134.3	358.71	3763.6	17942.8	23.713	36.861	30.22	6.4175	13602.1	311.47	109.93	36.121	647.8	1877.2	1
255		270-275	E704	8168.7	2840.5	321.68	3521.2	15346.8	44.427	32.737	23.974	10.207	14287.8	429.87	129.02	37.184	692.54	3111.3	1

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
256	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/Kg	P mg/Kg	S mg/Kg	Peat Type
257		290-295	E705	7173.6	3183.7	350.73	4010.1	17738.8	25.593	37.53	32.507	12.067	14854.7	404.74	133.08	41.538	594.61	2419.1	1
258		295-300	E706	5399.8	3438.2	405.22	4781	21002.3	19.78	41.938	34.053	13.113	14892.1	321.87	157.85	42.387	584.28	1489.8	1
259																			
260	SITE 27.3	0-5	E757	4487.8	1052.8	233.04	3308	1049.9	13.512	3.3893	<1.89	7.3474	840.02	375.24	28.084	11.719	980.01	810.46	
261		-10.00	E758	2868.5	618.26	107.42	1093.5	1792.2	12.788	12.321	2.0875	4.181	2611.7	24.857	25.314	4.0345	845.41	688.71	
262		20-25	E759	4295.8	741.79	57.327	171.88	1114.3	10.613	2.6975	<1.48	1.6855	1186	6.7707	20.18	1.5237	482.02	732.21	
263		33-35	E760	11487.1	1545.8	96.944	181.17	1858.4	23.892	2.5142	2.6828	3.1537	3480.3	14.27	32.848	2.0807	885	1413.8	
264		45-50	E761	5258	408.14	86.138	92.307	644.3	8.861	3.2569	<1.93	3.3368	1317.1	21.034	13.819	<1.27	266.38	698.79	
265		50-55	E762	6213.8	611.61	68.472	82.828	705.57	10.723	<2.34	<1.72	2.0111	1719.8	13.857	12.454	<1.13	280.88	862.32	
266		70-75	E763	7502.8	1183.8	91.05	60.782	582.7	10.002	<2.64	<1.94	3.5116	2341.8	22.801	13.888	<1.27	200.73	851.63	
267		90-95	E764	10647.8	1163.5	56.178	136.56	1807.8	25.288	4.4187	4.5524	2.1484	4170.6	34.961	7.8856	1.9368	372.55	1250.5	
268		105-110	E765	9848.1	1120.2	103.47	121.64	1561.4	26.008	<2.27	2.6398	2.611	4081.1	33.249	9.1678	<1.1	355.8	1217.8	
269		125-130	E766	12078.4	1317.3	78.971	105.27	1291.5	24.707	2.0661	6.6181	4.2695	6856.6	52.989	10.62	<0.8453	349.33	2250.1	
270		145-150	E767	11784.5	1487.1	104.01	192.58	2374.7	19.038	3.0186	9.3054	6.8817	8444.5	72.407	13.035	<1.02	595.58	4187.3	
271		164-169	E768	7056.3	2868.4	475.85	3813.8	21231.7	13.149	26.422	30.553	18.186	11779.4	76.899	91.586	<1.03	578.43	1580.1	
272																			
273	SITE 27.4	0-5	E769	3533.6	807.56	164.96	828.54	1644.8	14.517	69.204	4.0347	7.0374	1717.8	36.109	47.535	<1.38	885.8	909.06	8
274		-10.00	E770	4413.5	878.64	150.95	705.51	3107.9	16.127	9.4554	5.9349	4.276	1654.7	19.885	44.631	<1.39	711.48	1418.8	8
275		20-25	E771	6489.6	1232.2	106.2	255.4	1234.8	11.201	3.4141	3.9605	3.5559	1806.8	13.69	30.946	<1.0	571.45	1040.1	8
276		30-35	E772	6205.9	1242	91.391	174.34	1072.6	8.0808	2.8327	3.022	2.622	1760.9	13.64	19.951	<1.35	368.85	879.47	8
277		40-45	E773	5841	1229.8	117.5	425.06	2304.5	6.0121	4.7966	4.2748	2.7598	2137.7	28.716	22.109	<1.02	269.27	1076.5	8
278		60-65	E774	9692.8	1410.1	110.01	89.714	1185.7	14.941	2.5352	2.71	4.8324	3502.8	65.827	17.022	<1.11	411.4	1691.3	8
279		75-80	E775	8527	1191.8	67.424	105.72	1445.9	16.1	3.5962	6.4042	6.0015	3936.9	91.668	12.036	16.466	467.56	2226.5	7
280		91-95	E776	9768.6	1514.7	99.771	320.58	5284.1	23.081	9.8389	15.224	13.157	7027.7	173.47	15.784	<1.1	1080.1	4410.8	7
281		95-100	E777	7280.4	1877.5	305.59	1809	17015.7	10.808	16.249	20.837	16.222	8243.6	143.92	28.167	<1.070	1172.4	2378.6	7
282																			
283	SITE 35.1	0-5	E513	15861.7	1874.8	247.31	883.32	1292.1	18.298	<2.280	2.8821	8.5862	1343.8	89.548	115.78	18.488	1979.9	5999.9	3
284		-10.00	E514	25403.7	2504.3	296.25	441.56	1680.8	20.592	<2.230	3.8443	9.2514	2305.9	39.456	119.58	4.9357	1513.9	7807.5	3
285		15-20	E515	20924.2	2567.5	242.44	145.2	776.76	11.665	<2.280	2.1144	8.6673	1535.8	8.9161	104.59	11.175	1233.9	10497.4	3
286		25-30	E516	31934.7	2807.1	227.33	54.848	570.4	10.48	<2.280	1.73	7.7358	1257.4	3.387	105.93	3.7539	1075.4	12135.2	3
287		35-40	E517	33899.8	2648.4	206.98	82.592	921.85	13.786	<3.420	<2.49	11.387	3029.2	4.7313	122.39	128.91	1035.7	13407	3
288		45-50	E518	28821.1	2356.9	267.05	226.75	2810.7	18.45	<2.280	6.3111	15.12	3554.4	7.1449	116.87	16.697	879.20	12728.5	2
289		65-70	E519	8179.7	1507.2	247.24	1020.2	7628.8	28.628	<2.280	8.621	1.4743	4933.3	21.154	47.698	22.278	404.51	3393.8	2
290		85-90	E520	5377.2	1425.3	238.84	1379.3	7801.3	24.182	<2.280	7.977	1.5763	5120.5	27.973	50.141	8.5507	302.23	1734.8	1
291		105-110	E521	5735	1794.8	283.05	1939.1	9928.4	32.332	7.9574	12.666	5.1551	6167.5	48.521	65.146	20.545	354.4	1797.5	1
292		123-128	E522	6450.1	1799.3	450.78	2156.1	10040.2	19.739	4.4795	12.046	6.4869	5871.7	58.665	95.952	18.914	318.07	2428.3	1
293		135-140	E523	6033.8	1940.6	296.09	2296.8	11165.8	23.427	6.5348	12.174	5.4441	7131.6	58.833	80.345	13.4	368	2120.4	1
294																			
295	SITE 35.2	0-5	E524	15910.2	1990.3	191.01	828.13	4023.1	20.176	<2.260	5.0937	6.014	2907.5	79.98	113.46	15.559	1527.5	4972.8	3
296		-10.00	E525	27343.4	2162.3	162.84	231.51	982.41	13.772	<2.280	<1.66	6.8143	1517	10.081	17.227	7.056	1114	8304.5	3
297		20-25	E526	29790.5	2450.4	200.9	82.91	578.96	9.3291	<2.280	<1.66	5.3835	938.33	4.0841	45.938	4.032	1069.9	10307.1	3
298		30-35	E527	28081.3	2231.4	157.46	6030.1	658.49	10.722	<2.280	<1.66	6.8749	1483.9	3.0754	50.438	4.3275	837.13	9918.3	3
299		40-45	E778	32249.9	2734.2	194.77	126.88	1369.4	17.871	<2.680	<1.95	12.95	3211.4	4.8778	94.171	<1.3	909.68	13752.1	2
300		50-55	E528	34233.8	2705.1	227.28	214	1820.7	21.891	<2.280	4.4702	11.118	4000.2	8.12	105.28	20.492	993.25	13228.2	2
301		70-75	E529	25734	2218.8	221.79	674.21	5503.5	30.108	<2.280	9.8351	12.65	5686.3	15.634	118.21	18.287	1108.8	10305.9	1
302		92-97	E530	9768.6	2223.8	309.38	2010.5	11865.5	33.4	6.1132	13.423	3.2859	7061.7	33.69	82.48	14.08	553.85	3750.8	1
303		120-125	E779	2790.8	1829.2	395.84	2468.8	11923.3	9.4224	12.795	11.303	4.9202	5818.9	42.885	68.948	<0.7745	224.5	749.74	1
304		131-136	E531	2807.9	1731.3	339.9	2489.9	10178	21.532	9.5071	12.325	2.8398	9581.1	41.786	54.288	14.117	241.76	705.01	1
305		131-136RED	E780	2391.2	1675.5	361.94	2411.7	10176.9	9.409	12.276	10.489	3.3563	8445.8	37.858	50.587	<0.8489	218.99	784.03	1
306																			

Appendix III
Peat Chemistry - Elk Island National Park Continued

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
307	SITE	DEPTH (cm)	PEAT CHEM NO	Ca mg/Kg	Mg mg/Kg	Na mg/Kg	K mg/Kg	Al mg/Kg	Ti mg/Kg	Pb mg/Kg	As mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Zn mg/Kg	Ni mg/kg	P mg/Kg	S mg/Kg	Peat Type
308	SITE 36.3	0-5	E781	14828.9	2420.3	373.36	2018.3	8975.1	6.1882	15.073	10.966	10.305	7092	128.11	143.74	<1.09	1286.4	4908.1	3
309		-10.00	E782	28745.1	2527.7	199.1	978.96	8676	9.6844	10.866	11.599	11.245	6667	132.41	42.621	<0.863	371.68	6591.3	1
310		21-26	E783	16297.8	2591	320.91	1800.9	13791.5	31.298	15.997	15.652	17.338	8253.2	27.945	197.6	<0.9328	924.06	3431.2	1
311		28-33	E784	5639.8	1869.6	231.29	1706	12568.1	10.204	15.729	14.228	6.7456	6303.9	23.146	62.953	<1.04	316.84	853.89	1
312		40-45	E785	29911.8	2417.6	201.36	122.29	1215.3	16.617	<2.19	3.8448	12.992	2925.2	4.5748	82.528	<1.07	829.75	12478.1	1
313		45-50	E786	2885.6	2384.7	300.46	2338.7	12710.4	9.9678	16.675	13.738	2.4456	8686.8	43.591	37.53	<1.03	312.63	324.84	1
314																			
315	SITE 48.1	0-5	E532	43581.2	2966.6	3139.6	680.72	2633.9	34.926	<2.28	6.7596	6.3899	3394	276.92	58.145	10.793	1664.6	8913.4	3
316		-10.00	E533	44042.3	3021.6	2519.8	612.85	2977.6	36.245	<2.28	6.6194	6.3378	4148.8	178.37	64.144	6.3187	1108.4	11775.3	3
317		20-25	E534	39907.8	3019.9	3271.9	685.45	3336.6	39.403	<2.28	5.2046	6.7523	3385.6	76.534	25.479	7.7847	1487.9	13458.4	5
318		30-35	E535	32682.7	2469	3309.7	304	1289.7	22.186	<2.28	3.4279	6.402	3478.9	61.927	15.157	5.1095	1169.2	14781.4	3
319		40-45	E536	37202.8	2683.5	3318.6	491.51	2241.3	33.667	<2.28	4.2808	4.1953	4327.3	97.63	41.674	7.926	1102.4	14762.3	3
320		50-55	E537	32352.7	2318.2	2568.8	318.22	1811.4	28.41	<2.26	3.9404	5.0198	3292.1	82.214	23.424	6.6737	907.62	12869.6	3
321		70-75	E538	31821.6	2570.9	2727.3	660.94	4615.5	49.251	<2.280	6.6177	6.4141	4986.1	61.053	53.464	11.922	891.37	15486.7	3
322		90-95	E539	31626.7	2313.1	2603.9	452.61	3207.3	40.907	<2.280	8.0411	8.6451	6046.5	53.53	26.36	10.897	787.06	16873.7	3
323		110-115	E540	32753.8	2360.3	2351.5	776.81	4886	43.187	<2.280	9.0983	9.7608	4325.9	75.246	37.027	11.818	718.79	15008.8	3
324		130-135	E541	69955.7	3080.5	1887.1	1008.5	6346	53.154	<2.280	12.943	9.8456	4052.3	189.66	38.937	11.748	689.12	13478.7	1
325		150-155	E542	69072.5	4411.4	1664.3	1055.7	6333.7	67.577	<2.280	15.794	10.416	7309.9	412.76	51.688	12.131	716.03	15899.6	1
326		170-175	E543	68908.8	6866.1	1512.2	1568.6	7961.8	69.162	3.5717	17.434	13.402	9896.8	660.39	96.749	14.1	777.88	14847.5	1
327		190-195	E544	68883.5	8499.1	1541.9	1483.3	7293.8	43.444	<2.270	17.982	12.804	9059.2	602.76	57.135	164.6	729.95	13373.1	1
328		210-215	E545	69180.8	8652.7	1528.6	2288.6	10285.2	27.377	6.3767	23.13	14.029	11219.7	631.02	62.695	19.03	738.87	13176.1	1
329		234-239	E546	69248.8	7760.7	1326.5	1651.4	7249.4	30.385	4.0579	21.785	13.618	8198.5	850.11	38.7	14.738	418.07	10439.1	1
330		240-245	E547	69128.2	6863.2	1474.4	1000.4	4692.3	18.48	11.77	19.765	15.116	4886.4	902.46	37.425	13.679	298.6	9092	1
331																			
332	SITE 48.2	0-5	E787	28521.8	2881.1	1888.8	1070.3	2818.6	28.871	8.9758	4.3027	8.0303	2328.4	108.75	87.11	<1.16	1591.5	[illegible]	
333		-10.00	E788	37080.6	2901.8	2469.1	317.84	1822.2	28.003	21.67	9.7478	8.2404	2029.3	154.45	24.892	8.4773	1206.7	10900	
334		20-25	E789	40314.8	3113	2557.4	241.08	1786.6	25.223	<2.410	3.3119	5.9192	1591.1	86.537	34.758	<1.18	1198.4	12283.2	
335		30-35	E790	40129.9	2743.7	2979.6	198.03	1649.2	21.618	<2.39	3.3722	6.1526	3313.9	42.547	14.616	<1.17	829.85	16536	
336		40-45	E791	30242	2209.3	2887.4	251.06	2147.9	34.147	<1.84	4.8477	7.4874	4285.2	31.85	8.2128	<0.8995	903.82	14070	
337		50-55	E792	30211.1	2126.1	2983.1	171.56	1579.7	26.668	<2.09	4.4471	7.4782	4592.3	26.368	11.778	<1.02	816.56	16456.8	
338		70-75	E793	31489.1	2100.2	2580.8	392.89	3592.6	48.41	2.7489	6.4261	8.0613	5386.5	32.783	12.226	21.006	873.48	[illegible]	
339		90-95	E794	41132.6	2300.4	3113.5	311.22	2381.7	44.48	22.457	12.392	11.73	7454.2	51.697	10.054	15.459	688.82	18179.3	
340		110-115	E548	32100.7	2077.8	2709	514.37	4053.1	35.918	<2.28	8.5042	11.358	8774.7	69.056	29.254	11.695	740.7	18118	
341		130-135	E549	60986.5	2086.8	2287.3	614.08	4224.3	38.291	6.3813	9.668	13.201	7999.9	137.13	32.595	11.747	673.94	20000.2	
342		150-155	E550	54825.1	2650.3	2337.2	728.45	7228.7	50.149	2.8459	10.165	24.457	6067.8	108.71	191.82	12.903	1418.7	11178.9	
343		167-172	E551	69213.1	8470.9	1814.3	1483.2	7686.9	51.273	11.757	19.128	14.644	12123.9	856.86	66.177	19.186	708.45	15828.2	
344		183-190	E552	69001.7	8083.7	1576	2170.7	9725.2	25.046	14.081	24.491	14.221	15493.2	1088.4	50.978	19.399	625.62	14550.9	
345		205-210	E796	151126.3	6341.5	322.74	1616.3	7326.3	43.208	41.416	30.184	12.411	9127.7	985.97	28.718	23.579	349.8	8161.9	
346		210-215	E553	69226	5967.8	992.81	1537.6	6248.1	19.349	9.7541	14.834	10.17	6264.4	927.48	27.047	14.216	331.53	6168.5	
347																			
348	SITE 48.3	0-5	E554	69147.1	7597.8	1213.1	3687.5	14182.1	23.286	18.292	22.682	12.292	11331.7	1013.8	65.658	21.962	534.79	6395.3	4
349		-10.00	E555	36296.7	2207.7	2960.6	263.96	1753.6	27.512	<2.27	<1.65	8.6831	1981.9	51.349	80.778	6.2885	1224.1	12542.5	[illegible]
350		20-25	E556	34750.9	2018.6	2063.8	223.12	2148.4	29.225	<2.27	<1.86	13.228	3124.2	58.896	86.893	7.5935	899.03	18849.6	4
351		30-35	E557	35772.2	2023.2	2883.7	223.44	2165.7	30.096	<2.27	2.8745	18.137	4283.4	96.945	130.98	9.491	883.13	15411.5	3
352		40-45	E558	58829.3	1929.8	2379.8	257.34	2904.8	40.181	<2.27	4.8626	30.765	4006.9	[illegible]	263.88	10.263	1242.7	11713.1	3
353		50-55	E559	68787.5	3324.3	2279.8	1190.5	9596.4	[illegible]	12.295	12.006	14.886	9538.9	[illegible]	63.248	15.813	772.17	18689.8	3
354		70-75	E560	69101.4	5295.6	648.12	1870.9	11289.3	[illegible]	18.344	16.116	17.76	13233.3	463.06	99.967	24.486	721.6	2373.8	1
355		75-85	E799	116769.8	7064.8	954.2	2961.3	16269.3	128.42	24.744	27.008	12.981	18185.5	652.76	68.506	18.181	492.96	1171.8	1
356	Peat Type = categories 1-8 identified from peat macrofossils. See discriminant analysis section.																		
357	RE = A sample which was redone.																		