The vegetation of three *Sphagnum*-dominated basin-type bogs in northeastern Ohio[1]

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ABSTRACT. **Vegetation and selected ground water characteristics were examined for three closely proximate basin-type bogs in northeastern Ohio. These peatlands exhibit "zonation", with a low shrub zone dominated by *Chamaedaphne calyculata* (Frequency-Presence Index [FPI] 4433) and *Decodon verticillatus* (FPI 5400) adjacent to and invading the open water. A tall shrub zone, extending aproximately 5 to 10 m to the exterior of the low shrub zone, is dominated by *Vaccinium corymbosum* (FPI 5533), *Gaylussacia baccata* (FPI 3133), and *Nemopanthus mucronatus* (FPI 2200). Extending for the next 5 - 10 m is a tree zone, dominated by *Larix laricina* (FPI 800), *Betula alleghaniensis* (FPI 198), and *Nyssa sylvatica* (FPI 77). *Sphagnum recurvum* (*sensu lato*) (FPI 6500) forms a more or less continuous mat throughout the bogs. The vegetation of the three peatlands is similar, with similarity indices (c) ranging from 0.59 to 0.67. Based on pH, conductivity and Ca and Mg ion concentrations, these peatlands are semi-ombrotrophic to weakly minerotrophic. These communities, located near the glacial boundary, represent northern peatlands at the southern edge of glaciation.**

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INTRODUCTION

Early investigations of peatlands, including those with an ecological perspective, were primarily qualitative in nature. Classic studies, such as those of Dachnowski (1912), Gates (1942), Aldrich (1943), Conway (1949) and Dansereau and Segadas-Vianna (1952), emphasized peatland development related to floristics. More recently, in-depth quantitative studies have correlated physical development, water chemistry, and phanerogam and bryophyte floras. Through these studies, microhabitats were identified within extensive peatlands in Minnesota and Canada, where peatlands cover thousands of hectares (Glaser et al. 1981, Wheeler et al. 1983, Karlin and Bliss 1984).

Ohio peatland studies have been floristic in nature (Selby 1901, Detmers 1912, Jones 1941, Frederick 1974, Andreas 1980). In his survey of Ohio peatlands, Dachnowski (1912) estimated that less than one percent of Ohio's land surface (approximately 74,000 ha) was occupied by peat at the time of European settlement. Today, few floristically intact communities remain (Andreas and Host 1983, Andreas 1985). For that reason, taxa confined to peatlands are locally "rare", and numerous peatland taxa are present on the Ohio rare plant list (Division of Natural Areas and Preserves 1988).

Among the rarest types of Ohio peatlands is the kettle-hole bog, which exhibits concentric vegetational zonation including *Larix laricina* (tamarack). Kettle-hole bogs are basin-type wetlands that are underlain by peat and have a *Sphagnum* mat surrounding a lake in a glacial kettle-hole or similar depression (Vitt and Slack 1975). Selby (1901) prepared a preliminary list of 27 tamarack bogs in Ohio. There are now approximately ten well developed basin-type bogs with tamarack extant in Ohio, three of which remain relatively undisturbed. These are Fern Lake Bog, Geauga County, and Flatiron Lake Bog and Triangle Lake Bog, Portage County, subjects of this study.

The occurrence of kettle-hole bogs in Ohio is noteworthy because these sites are at the southernmost edge of the region occupied by glacially-created kettle-hole bogs in eastern North America. These communities, similar in latitude, geologic age and flora to those described in New York and New Jersey (Lynn 1984, Lynn and Karlin 1985), are small in terms of area compared to expansive peat deposits of more northern latitudes. Data from these areas may be useful in assessing ecological and successional trends in peatlands, because these areas have been available for plant colonization for a much longer period of time than peatlands in northern Michigan, Minnesota, Wisconsin, Maine, New Hampshire, Vermont and Canada.

The purposes of this research were: 1) to examine quantitatively floristic composition and structure of basin-type (kettle-hole) bogs; 2) to determine certain water chemistry characteristics of these areas; 3) to classify these peatlands within a classification system which is based on water chemistry variables; and 4) to correlate floristics of Ohio kettle-hole bogs with geologically younger bogs in northern latitudes.

STUDY AREA

The kettle-hole bogs sampled in this study are located in northeastern Ohio in the Glaciated Allegheny Plateau physiographic region (Fenneman 1938). The three bogs are each part of a larger peatland complex, and each has a well-defined outlet but no distinct inlet. The depression surrounding Fern Lake Bog has intermittent drainage from neighboring fields. Each kettle-hole bog occurs on glacial material above a pre-Wisconsinan buried river valley (Andreas 1985). These areas are separated from each other by a maximum distance of 48 km (Table 1).

Climate at Hiram, OH (16 km from the northernmost and southernmost study area) has mean annual precipitation of 103.8 cm, and mean annual snowfall of 154.7 cm. Mean January temperature is -3.5° C, and mean July temperature is 21.6° C, with a mean annual temperature

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of 9.6° C. The average number of frost-free days is 165 days (Ruffner 1980).

Bedrock consists of Pennsylvanian-age sandstones (White 1982), but mineral soils present today are derived from glacial materials deposited by several Pleistocene advances. Mineral soils of the watershed surrounding the depressions primarily are well-drained Chili soils that form on outwash plains, kames and stream terraces. These upland soils are vegetated with beech-maple (*Fagus grandifolia - Acer saccharum*) forests with occasional patches of mixed oaks, but agricultural fields lie in close proximity to each bog. Soils of the depressions are organic and are classified as Carlisle muck (Ritchie et al. 1978, Williams and McCleary 1982).

The three basin-type bogs occur within the Kent Moraine in an interlobate area between the Killbuck and Grand River lobes of late Wisconsinan glaciation (White 1982). The Kent Moraine is an irregular belt of hummocky topography where "the marginal ice stagnated in a belt ranging up to 15 miles wide, and masses of till and gravel were deposited in a confused mass around ice blocks, in holes and low places in the ice, and on top of the dissipating ice" (White 1982). The bulk of the Kent Moraine was deposited by the Titusville ice sheet of Altonian age, which advanced out of the Erie basin about 40,000 B.P. (years before present). This morainal system was again covered by younger tills, primarily with Kent Till about 20,000 B.P. White (1982) and Shane (1975) indicate younger Lavery tills as occurring within a mile of one of the study areas (Triangle Lake Bog). Based on pollen studies and radiocarbon dating from a nearby depositional basin, Shane (1987) estimated that the area was ice free, and deposition began at least 15,700 B.P. The study sites probably have been available to vegetation since that time. Peatlands in northern lower Michigan have been subject to peatland development for about 10,000 years (Schwintzer 1978b), and those in the Red Lake peatland area in Minnesota, from about 1950 ± 65 B.P. (Glaser et al. 1981).

Historical botanical data are available for Fern Lake Bog (Selby 1901, Dachnowski 1912, Gersbacker 1939, Aldrich 1943, Medve 1958). Triangle Lake Bog was described in Herrick (1974), and a preliminary floristic list was prepared by Andreas (1980). This study is the first report of the flora of Flatiron Lake Bog.

MATERIALS AND METHODS

During June and July, 1984, the vegetation at each study site was sampled along four belt transects that extended from the open bog lake radiating in north-south and east-west directions for a minimum of 20 m or to the outer edge of the tamaracks. A minimum of 76 1 x 2 m contiguous quadrats was sampled at each study area for the tree and shrub layers. At each study area, a minimum of 66 1 x 1 m quadrats was located by means of random numbers, both inside and outside of the belt transects, and these quadrats were sampled for the herbaceous and ground layers. Adequacy of vegetation sampling was determined at each site by plotting species on a species-area curve (Brower and Zar 1977). Vegetation of the marginal moat and swamp thicket-tall shrub zones was sampled visually for species present.

For this study, the tree layer included single-stemmed woody species with a diameter at breast height (dbh) greater than 5 cm. The shrub layer included all multi-stemmed woody species, the woody-based perennial *Decodon verticillatus* (swamp loosestrife), and single-stemmed woody species with a dbh of less than 5 cm. The herbaceous layer included all herbaceous species, sub-shrubs, including *Vaccinium macrocarpon* (large cranberry), *V. oxycoccos* (small cranberry), *Gaultheria procumbens* (wintergreen), and *Mitchella repens* (partridge-berry), and seedlings of woody species less than 30 cm in height. The ground layer included all bryophytes.

Presence and a visual estimation of percentage cover were determined for each vascular plant and bryophyte species. In each quadrat, species with little significant cover were recorded as having 1% cover. Visual estimation of percentage cover was aided by using a meter frame subdivided into 20 x 20 cm subquadrats, where the cover of each subquadrat was estimated and added together for the total percentage cover of that quadrat. Importance values (IV) were calculated for each species as the sum of the relative frequency and the relative cover, divided by two, giving a summation constant of 100.

Frequency-presence index (FPI) was calculated for each taxon in each vegetation layer as the percentage presence multiplied by the mean percentage frequency (Table 3). This frequency-presence index has a maximum value of 10,000 (100% presence x 100% frequency) for a taxon found in all quadrats in all study areas, and a minimum value approaching zero for a rare plant found in only one quadrat in only one study area. Frequency-presence index is a measurement of the commonness of the plant in the three study areas, and is directly related to the chances of finding that particular species at any given point in any given community (Curtis 1959).

Floristic similarity (2w/a+b) was determined by the method presented in Curtis (1959) for each pair of communities using a measure based on species presence where "a" = the number of species in one community, "b" = the number of species in a second community, and "w" = the number of species common to both community a and b. The index ranges from 0 to 1.0 and expresses the range of similarity from complete similarity at 1 and no similarity at 0.

Voucher specimens for vascular plants were deposited in the Kent State University Herbarium (KE), and voucher specimens for bryophytes at the University of Cincinnati Herbarium (CINC). Nomenclature for vascular plants primarily follows Voss (1972, 1985); for mosses, Crum (1983); and for liverworts, Steere (1940).

A minimum of three water samples was collected from the open lake and *Sphagnum* mat at each study site during May - September, 1985. *Sphagnum* mat sample sites were visually selected to represent the variability of the community as reflected by the vegetation. A permanent sampling site was established in the substrate within a belt transect at each study site by digging a well to a depth of 30 cm, removing the vegetation, placing a polyvinyl cylinder within the well and taking monthly water samples from the cylinder. Each month, samples

TABLE 1

Location and area information of the study sites.

	Fern Lake Bog	Flatiron Lake Bog	Triangle Lake Bog
County	Geauga	Portage	Portage
Location	N 41° 26'; W 81° 10'	N 41° 2'; W 81° 22'	N 41° 77'; W 81° 15'
Elevation (m)	344	365	328
area of depression (ha)	19	12	5
area of open lake (ha)	1.0	0.2	1.0

were collected at random by the "press method", in which polyethylene and glass bottles were gently pressed in the substrate.

The pH, adjusted to a standardized temperature of 20° C, was determined in the field with an Orion 200 field pH meter, and specific conductance (25° C) was determined with a Fisher conductivity meter Model 152. Water samples were placed on ice and taken to the laboratory, where they were passed through large-pore filters and frozen. Final chemical analyses were completed within six weeks after collection. Calcium and magnesium values were determined with a Perkin-Elmer 2280 atomic absorption spectrophotometer using a hollow cathode lamp and methods listed in the operation manual (Perkin-Elmer 1973).

RESULTS AND DISCUSSION

Vegetational Analysis

The three kettle-hole bogs are each part of larger peatland complexes ranging in size from 5 to 19 ha (Table 1). Kettle-hole bog formation at these sites appears to be similar to the model proposed by Kratz and DeWitt (1986), where the organic substrate of the depression can be separated into a floating mat, which encroaches upon the open lake, and a grounded mat. The grounded mat may be divided into a zone of compaction where there is active peat accumulation, and a zone of equilibrium where there is no peat accumulation. Between the zone of equilibrium and the upland is a region referred to as the marginal moat, lagg, or marginal fen (Conway 1949, Vitt and Slack 1975). While the width and vegetation of the moat varies at each locality, typical species found in this zone are similar (Table 2).

From the interface of the upland to the open bog lake, the following occur: marginal moat zone, swamp thicket-tall shrub zone, treed bog zone, tall shrub zone, and low shrub zone. These vegetation zones are typical (Vitt and Slack 1975, Lynn 1984, Lynn and Karlin 1985). Vascular plants in the marginal moat and swamp thicket-tall shrub zone were surveyed visually.

The marginal moat zone, with standing water at least part of the growing season, is primarily open with few trees. The water table tends to be lower from mid-August to early March. Hummocks form around the bases of shrubs, but *Sphagnum* seldom forms a continuous cover. The width of the moat and dominant taxa varied from area to area, but species composition remained relatively constant (Table 2). The flora of the marginal moat blends into a swamp thicket-tall shrub zone.

The swamp thicket-tall shrub zone occupies the largest percentage of the vegetated surface area of the three depressions. From visual examination, this area is dominated by the same taxa that occur within the sampled area, especially *Vaccinium corymbosum* (northern highbush blueberry). *Acer rubrum* (red maple), *Betula alleghaniensis* (yellow birch), *Nyssa sylvatica* (black gum), and occasionally *Larix laricina*, are scattered throughout the swamp thicket-tall shrub zone. Many trees in this zone are dead, probably from flooding with cyclic water table fluctuations. Schwintzer and Williams (1974) described tree mortality in a Michigan bog caused by cyclic water table fluctuations. The swamp thicket-tall shrub zone is less developed at Triangle Lake Bog, where a large percentage of the depression is vegetated by a *Carex - Dulichium* meadow, with dead shrubs scattered throughout. The fluctuating water table caused by a sporadic (since 1978) beaver population at Triangle Lake Bog would result in such an effect.

The treed bog zone and tall and low shrub zones were surveyed quantitatively for tree, shrub, herbaceous, and ground vegetation layers.

TREE LAYER. A "bog forest", in the context of Lynn (1984), or "treed bog" (Jeglum et al. 1974), is not well developed at the study areas. At each study area, a narrow, more or less concentric zone of trees (bog forest) extends from 10 to 30 m from the open lake. All vegetation falling within the tree layer (Table 3) was found in the treed bog zone. *Larix laricina* (FPI 800), *Betula alleghaniensis* (FPI 198), and *Nyssa sylvatica* (FPI 88), reached tree size (a dbh greater than 5 cm) (Table 3). Hardwood species in the tree layer at Fern Lake Bog were removed by beaver. Trees of *L. laricina* remaining at Fern Lake Bog show signs of stress from girdling, and many crowns of the remaining *Larix* are depauperate. *Larix* appeared as a shrub in only 2% of the plots sampled at Fern Lake Bog, whereas it was present in 25% of the plots at Flatiron Lake Bog, and in 13% of the plots at Triangle Lake Bog. During the 1984 and

TABLE 2

Vascular plants present in the marginal moat of the study sites.

Species	Fern Lake Bog	Flatiron Lake Bog	Triangle Lake Bog
Acer rubrum	X	X	X
Aronia prunifolia		X	X
Betula alleghaniensis	X	X	X
Bidens coronata	X	X	X
Calla palustris	X	X	X
Carex crinita	X		X
Carex canescens	X	X	X
Carex howei	X		X
Carex tenera			X
Carex trisperma	X	X	X
Cephalanthus occidentalis		X	X
Chamaedaphne calyculata			X
Cicuta bulbifera	X		X
Decodon verticillatus	X		X
Dulichium arundinaceum	X	X	X
Gaylussacia baccata		X	X
Glyceria striata		X	
Hypericum virginicum	X	X	X
Ilex verticillata	X	X	X
Juncus canadensis			X
Juncus effusus	X	X	X
Leersia oryzoides	X	X	
Lycopus virginicus	X		X
Lysimachia terrestris	X		X
Nemophanthus mucronatus	X	X	X
Nyssa sylvatica	X	X	X
Osmunda cinnamomea	X	X	X
Polygonum hydropiperoides	X		X
Polygonum arifolium	X	X	
Rhamnus frangula	X		X
Rhus vernix	X	X	X
Rubus hispidus var *obovalis*	X	X	X
Sagittaria latifolia	X		X
Scirpus cyperinus	X	X	X
Spiraea alba			X
Thelypteris palustris	X		X
Typha latifolia	X	X	X
Vaccinium corymbosum	X	X	X
Viburnum recognitum	X		X
Woodwardia virginica		X	X

1985 field seasons, we noted that at Fern Lake Bog the one- and two-year-old seedlings were cut off at ground level, possibly by rodents (Duncan 1954). Medve (1958) noted a 41% decline in *Larix* between 1939 and 1958, but did not offer an explanation. At Triangle Lake Bog and Flatiron Lake Bog, tamarack regeneration is limited to the floating mat and consolidated mat zone, where low shrubs and open *Sphagnum* pockets allow for abundant light.

Medve (1958) indicated that part of the bog forest at Fern Lake Bog was lumbered in 1936. A 1937 U.S.D.A. Soil Conservation Service aerial photograph confirmed that lumbering occurred approximately 0.05 km south of Fern Lake Bog. Aerial photographs dating from 1937 to 1986 of Fern Lake Bog, Triangle Lake Bog and Flatiron Lake Bog, indicate that no additional clear cutting occurred and changes in the tree layer surrounding the basin-type bogs occurred primarily because of either water level changes or beaver activity.

Acer rubrum typically is a component in the tree layer of peatlands (Schwintzer 1978a, Sytsma and Pippen 1982, Lynn 1984, and Dunlop 1987). We found red maple in every transect sampled at the three bogs, but red maple did not attain a dbh greater than 3.2 cm on the bog mat within the ring of tamaracks. According to Moizuk and Livingston (1966), nitrogen deficiency in the *Sphagnum* mat limits growth in red maple. *A. rubrum* attained tree size throughout the swamp thicket-tall shrub zone and,

TABLE 3

Vegetation of the bog mat at Fern Lake Bog, Geauga County, Ohio; Flatiron Lake Bog and Triangle Lake Bog, Portage County, Ohio.

Layer/Species	Frequency-Presence Index	Fern Lake Bog % cover	Fern Lake Bog % frequency	Fern Lake Bog % IV	Flatiron Lake Bog % cover	Flatiron Lake Bog % frequency	Flatiron Lake Bog % IV	Triangle Lake Bog % cover	Triangle Lake Bog % frequency	Triangle Lake Bog % IV
Tree Layer										
Larix laricina	800	5.0	8.0	100	3.0	7.0	71	9.8	9.0	61
Betula alleghaniensis	198	-	-	-	0.9	4.0	29	0.9	5.0	17
Nyssa sylvatica	77	-	-	-	-	-	-	1.0	7.0	21
Shrub Layer										
Vaccinium corymbosum	5533	15.0	49.0	20	30.0	66.0	32	19.0	51.0	20
Decodon verticillatus	5400	16.0	54.0	21	16.0	40.0	18	31.0	68.0	30
Chamaedaphne calyculata	4433	8.0	30.0	11	20.0	56.0	25	10.0	47.0	15
Gaylussacia baccata	3133	8.0	27.0	10	13.0	29.0	13	17.0	38.0	17
Nemopanthus mucronatus	2200	17.0	43.0	21	2.0	5.0	2	4.0	18.0	6
Larix laricina	1333	0.5	2.0	1	3.0	25.0	7	1.0	13.0	3
Acer rubrum	800	0.6	13.0	3	0.6	7.0	2	0.5	4.0	1
Ilex verticillata	682	2.5	15.0	5	-	-	-	4.0	16.0	5
Aronia prunifolia	374	0.7	13.0	3	-	-	-	0.9	5.0	1
Betula alleghaniensis	352	0.5	5.0	1	0.7	11.0	3	-	-	-
Rhus vernix	330	1.5	11.0	3	-	-	-	0.1	4.0	<1
Nyssa sylvatica	44	0.2	4.0	<1	-	-	-	-	-	-
Rhamnus frangula	33	-	-	-	-	-	-	0.5	4.0	<1
Viburnum recognitum	22	0.2	2.0	<1	-	-	-	-	-	-
Herbaceous Layer										
Carex canescens	2566	2.7	43.0	7	0.4	20.0	7	0.9	14.0	5
Hypericum virginicum	2373	3.0	40.0	7	0.1	8.0	2	3.0	22.0	12
Vaccinium macrocarpon	1733	2.0	8.0	4	4.0	36.0	27	2.0	8.0	6
Woodwardia virginica	1653	3.0	28.0	6	1.4	8.0	7	0.6	14.0	4
Acer rubrum	1298	0.7	39.0	4	0.2	20.0	2	-	-	-
Carex trisperma	1266	5.0	23.0	7	1.0	9.0	7	0.4	6.0	3
Rhynchospora alba	1150	1.0	7.0	2	0.1	6.0	2	-	-	-
Drosera rotundifolia	1122	1.0	15.0	2	0.9	36.0	13	-	-	-
Maianthemum canadense	945	1.6	31.0	5	-	-	-	0.7	12.0	4
Lycopus virginicus	783	0.4	20.0	2	0.1	2.0	<1	<0.1	2.0	1
Vaccinium corymbosum	783	<0.1	7.0	<1	<0.1	3.0	1	0.6	14.0	5
Sarracenia purpurea	678	-	-	-	1.0	17.0	8	0.7	12.0	4
Rhamnus frangula	495	<0.1	7.0	<1	-	-	-	0.7	16.0	5
Utricularia vulgaris	396	0.3	8.0	1	-	-	-	1.0	10.0	5
Utricularia minor	385	-	-	-	1.0	2.0	10	0.9	16.0	6
Carex howei	383	0.6	5.0	1	0.5	5.0	1	0.1	2.0	<1
Calla palustris	363	0.8	15.0	2	0.7	2.0	1	-	-	-
Bidens spp.	334	0.2	3.0	<1	-	-	-	0.1	12.0	3
Larix laricina	334	0.1	3.0	1	0.4	12.0	5	-	-	-
Cuscuta gronovii	297	-	-	-	-	-	-	5.0	27.0	16
Symplocarpus foetidus	260	0.7	10.0	2	-	-	-	0.1	2.0	<1
Betula alleghaniensis	242	0.5	7.0	1	0.5	5.0	1	-	-	-
Nemopanthus mucronatus	231	0.1	7.0	<1	-	-	-	<0.1	4.0	1
Bidens coronata	220	0.3	20.0	2	-	-	-	-	-	-
Decodon verticillatus	176	0.8	7.0	2	0.2	2.0	<1	-	-	-
Rhus vernix	176	-	-	-	-	-	-	0.3	22.0	6
Carex atlantica	165	3.0	15.0	5	-	-	-	-	-	-
Gaultheria procumbens	165	0.8	15.0	2	-	-	-	-	-	-
Peltandra virginica	165	2.0	15.0	3	-	-	-	-	-	-
Thelypteris palustris	165	5.0	15.0	8	-	-	-	-	-	-
Coptis trifolia	143	1.0	13.0	3	-	-	-	-	-	-

TABLE 3 Continued

Layer/Species	Frequency-Presence Index	Fern Lake Bog % cover	Fern Lake Bog % frequency	Fern Lake Bog % IV	Flatiron Lake Bog % cover	Flatiron Lake Bog % frequency	Flatiron Lake Bog % IV	Triangle Lake Bog % cover	Triangle Lake Bog % frequency	Triangle Lake Bog % IV
***Herbaceous Layer**, continued*										
Leersia oryzoides	143	0.3	13.0	1	-	-	-	<0.1	2.0	1
Galium tinctorium	142	0.3	13.0	1	-	-	-	-	-	-
Cicuta bulbifera	121	0.7	10.0	2	-	-	-	-	-	-
Rubus hispidus var. obovalis	121	0.8	11.0	2	-	-	-	-	-	-
Juncus canadensis	88	0.5	8.0	1	-	-	-	-	-	-
Mitchella repens	79	<0.1	2.0	<1	-	-	-	-	-	-
Dulichium arundinaceum	71	<0.1	7.0	<1	-	-	-	-	-	-
Impatiens capensis	71	0.4	7.0	<1	-	-	-	-	-	-
Lemna minor	71	<0.1	7.0	<1	-	-	-	-	-	-
Polygonum arifolium	71	0.3	7.0	<1	-	-	-	-	-	-
Nyssa sylvatica	66	-	-	-	-	-	-	<0.1	6.0	2
Ludwigia palustris	56	0.2	5.0	1	-	-	-	-	-	-
Carex comosa	55	0.5	5.0	1	-	-	-	-	-	-
Carex spp.	55	0.1	5.0	<1	-	-	-	-	-	-
Ilex verticillatus	44	-	-	-	-	-	-	<0.1	4.0	1
Drosera intermedia	35	0.7	3.0	1	-	-	-	-	-	-
Eleocharis olivacea	35	0.1	3.0	<1	-	-	-	-	-	-
Ludwigia alternifolia	35	<0.1	3.0	<1	-	-	-	-	-	-
Medeola virginiana	35	<0.1	3.0	<1	-	-	-	-	-	-
Vaccinium oxycoccus	35	0.2	3.0	<1	-	-	-	-	-	-
Viola spp.	35	0.2	3.0	<1	-	-	-	-	-	-
Xyris difformis	33	-	-	-	0.2	3.0	1	-	-	-
Gaylussacia baccata	22	-	-	-	-	-	-	0.1	2.0	1
Bartonia virginica	18	0.1	2.0	<1	-	-	-	-	-	-
Chamaedaphne calyculata	18	<0.1	2.0	<1	-	-	-	-	-	-
Typha latifolia	18	<0.1	2.0	<1	-	-	-	-	-	-
Quercus sp.	17	-	-	-	<0.1	1.0	<1	-	-	-
Ground Layer										
Sphagnum recurvum	6500	34.0	64.0	52	23.0	70.0	69	31.0	61.0	76
Aulacomnium palustre	1400	2.0	31.0	10	0.2	3.0	2	0.4	8.0	4
Sphagnum fimbriatum	1383	8.0	30.0	17	<0.1	2.0	<1	1.0	10.0	7
Sphagnum palustre	671	4.0	20.0	10	-	-	-	17.0	8.0	7
Tetraphis pellucida	981	-	-	-	0.1	3.0	2	0.1	6.0	3
Sphagnum capillifolium	176	5.0	16.0	10	-	-	-	-	-	-
Cephalozia connivens	154	-	-	-	0.1	5.0	2	<0.1	2.0	1
Leucobryum glaucum	110	-	-	-	0.2	3.0	2	<0.1	2.0	1
Sphagnum magellanicum	99	-	-	-	0.2	9.0	16	-	-	-
Cladopodiella fluitans	88	-	-	-	0.3	8.0	4	-	-	-
Mylia anomala	56	-	-	-	<0.1	5.0	2	-	-	-
Pallavicinia lyellii	18	<0.1	2.0	<1	-	-	-	-	-	-
Sphagnum papillosum	17	-	-	-	1.0	2.0	2	-	-	-

infrequently, in the marginal moat. Sytsma and Pippen (1982) noted that in the Hampton Creek complex in southern Michigan tamaracks were replaced by *A. rubrum* and *Betula alleghaniensis*.

Nyssa sylvatica is frequent in the tree layer, especially at Triangle Lake Bog, and is found throughout the swamp thicket-tall shrub bog at the three study sites. Crow (1969) mentioned *N. sylvatica* as a component of the tree layer of bogs in southern Michigan. In Michigan, *N. sylvatica* is found in wet depressions in woods and along borders of swamps, occasionally with tamarack, but the taxon is rare above the 44th parallel (Voss 1985). Curtis (1959) makes no mention of *Nyssa* associated with wetlands in Wisconsin. From field reconnaissance elsewhere in northeastern Ohio, *N. sylvatica* is a frequent component of basin-type bogs.

Picea mariana (black spruce) is present in basin-type bogs in Michigan, Wisconsin and New York (Curtis 1959, Schwintzer 1978a, 1978b, Lynn 1984), but is not found in Ohio peatlands, or elsewhere in the state. Although no historical records for this taxon are known from Ohio, Shane (1987) listed spruce in pollen profiles for northeastern Ohio.

Shrub Layer. The shrub layer is best developed in the tall and low shrub zones, but shrubs extend into the treed bog zone as understory species. Dominant species in this vegetation layer were ordered by descending frequency-presence index (Table 3). Fourteen species were found in the shrub layer, and seven species were common to all three sites. Smoothed curve graphs for each peatland depict the sum total percentage cover of the significant shrub taxa in relation to the distance from the open water (Figs. 1-3). These graphs illustrate that the same taxa have repeating patterns within the peatlands, yet each taxon is distributed somewhat individually.

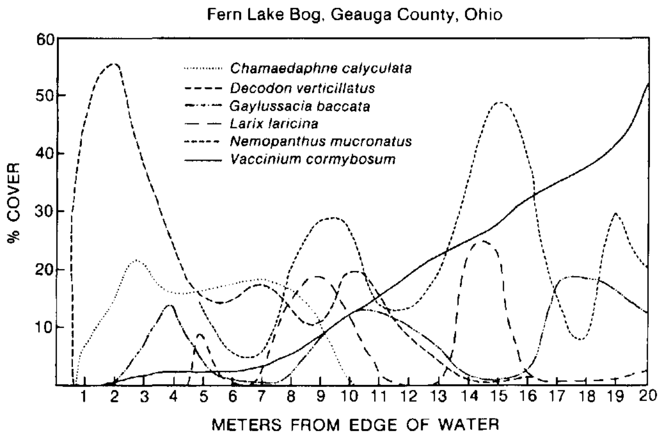

Figure 1. Smoothed curves of percentage cover of major shrubs along a transect from open water through 20 m (Fern Lake Bog, Geauga Co., OH).

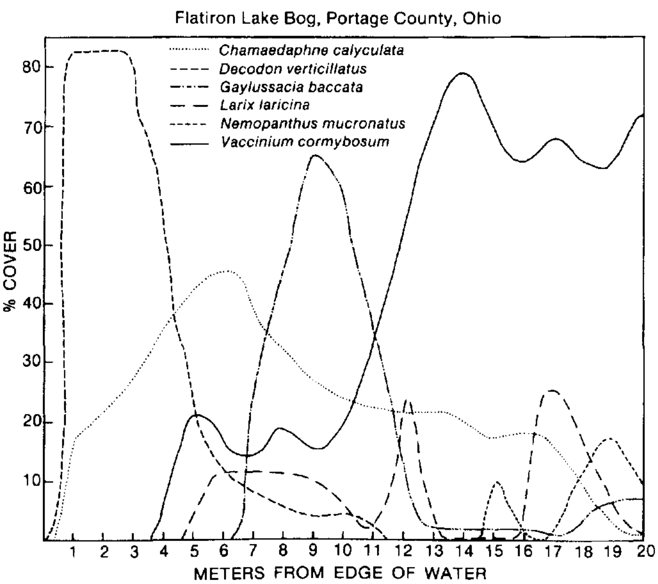

Figure 2. Smoothed curves of percentage cover of major shrubs along a transect from open water through 20 m (Flatiron Lake Bog, Portage Co., OH).

The floating, unconsolidated mat at the study areas, from 1 to 5 m in width, is dominated by low shrubs, predominantly *Decodon verticillatus* (FPI 5400) and *Chamaedaphne calyculata* (FPI 4433). At Fern Lake Bog and Flatiron Lake Bog *D. verticillatus* is the purchase, or forerunner, taxon making up about 55% to 80% of the cover. At Triangle Lake Bog, both *Decodon* and *C. calyculata* are forerunner taxa. *C. calyculata* commonly is found in the low shrub zone in peatlands throughout glaciated Eastern North America. For example, in Schwintzer's (1978a) comparison of six upper lower Michigan bogs, *Chamaedaphne* had a frequency-presence index of 7400. Swan and Gill (1970) described the role of *Chamaedaphne* in mat formation in an open lake in Massachusetts. *D. verticillatus* is common in bogs below the tension zone (Buell and Buell 1941, Crow 1969), but is rare in Michigan, Minnesota and Wisconsin above the tension zone. *Andromeda glaucophylla* (bog rosemary) and *Kalmia polifolia* (bog laurel), typically present in northern bogs, are absent from the modern Ohio flora; *Andromeda glaucophylla* is known from historical Ohio records, but *K. polifolia* has never been documented from the state.

The shrub layer within the tall shrub zone is dominated by *Vaccinium corymbosum* (FPI 5533), *Gaylussacia baccata* (huckleberry) (FPI 3133), *Nemopanthus mucronatus* (mountain-holly) (FPI 2200), *Larix laricina* (FPI 1333), and *Acer rubrum* (FPI 800). Flatiron Lake Bog and Triangle Lake Bog are similar in composition, although percentage cover varies (Figs. 2 and 3). *Nemopanthus mucronatus, Acer rubrum* and *Betula alleghaniensis* (FPI 352) become increasingly prominent around 10 to 14 m from the open water and form the understory beneath the tamaracks and hardwood trees. This composition is similar to that described by Crow (1969), Lynn (1984) and Lynn and Karlin (1985), but these taxa are not mentioned by Schwintzer (1978a). The irregular composition of the tall shrub zone at Fern Lake Bog (Fig. 1) is probably the result of recent water level fluctuations and of the removal

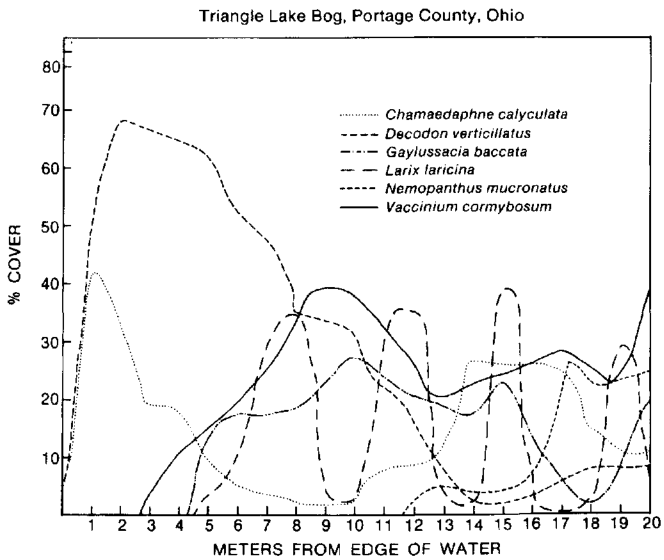

Figure 3. Smoothed curves of percentage cover of major shrubs along a transect from open water through 20 m (Triangle Lake Bog, Portage Co., OH).

by beaver of selected taxa. *Larix laricina* appears to exhibit a ring pattern while a component of the shrub community (Figs. 1-3).

Where the mat is consolidated and supports trees, *Nemopanthus mucronatus* becomes dominant. This taxon decreases in importance in the swamp thicket-tall shrub zone at Triangle Lake Bog and Flatiron Lake Bog, but increases at Fern Lake Bog. *Vaccinium corymbosum* continues to increase in percentage cover throughout the consolidated mat towards the marginal moat at the three study areas. *Chamaedaphne calyculata* continues to be present as an understory shrub, but quickly decreases in percentage cover beyond the tamaracks.

Studies spanning more than 50 years provide an opportunity to compare changes that have taken place in the shrub zones at Fern Lake Bog. According to Aldrich (1943) and Medve (1958), the width of the *Decodon* zone has remained about the same (Fig. 1). In Aldrich's (1943) simplified transect, *Chamaedaphne* appeared approximately 6 m from the open water, and in Medve's (1958) transects, it appeared about 3 m from the open water. In the present study, *Chamaedaphne* occurs, along with *Decodon,* at the water edge. Aldrich (1943) reported *Nemopanthus* occurring at 15 m from the open water, and Medve (1958) , at 5 m. In the present study, this taxon also appears around 5 m from the open water. Medve (1958) reported *Vaccinium corymbosum* as appearing about 6 m from the open water, and Aldrich (1943), about 23 m from the open water. In the present study this taxon was found near the open water. However, even though *V. corymbosum* has changed positions in the mat, it has remained near the same percentage frequency (48.6% in 1958, 49% in 1984). *Gaylussacia baccata* appeared 9 m from the open water in Aldrich's (1943) report, and about 3 m in Medve's (1958) report. Presently, *Gaylussacia* is found within 2 m of the open water. According to Medve, this taxon had a percentage frequency of 68.6% in 1939, 22.9% in 1958, and its current percentage frequency is 27%. Apparently *Ilex verticillata* (winterberry) appeared about 23 m from the open lake in Aldrich's (1943) study, was not mentioned in a 1939 report cited by Medve (1958), but reached 6% in frequency in 1958. In the present study, this taxon was found within 5 m of the open water and has a percentage frequency of 15%.

Based on historical Soil Conservation Service aerial photographs and a photograph in Dachnowski (1912), the decrease in width of the floating mat at Fern Lake Bog is a recent phenomenon. The mat has decreased on the south side, and all but disappeared on the east, north and west sides of the lake. In the field, it is possible to walk on an underwater "ledge" that extends out into the lake for approximately one meter. Although Buell and Buell (1941) discussed the ability of the floating, unconsolidated mat to rise with water level changes, at Fern Lake Bog this apparently did not happen.

Herbaceous Layer. Herbaceous taxa typically associated with bogs were found at the interface between the floating mat (low shrub zone) and the grounded mat (tall shrub zone). Lynn and Karlin (1985) described a similar interface. In the present study, the width of this interface varies from less than 30 cm to approximately 3 m, and includes the following taxa: *Vaccinium macrocarpon, V. oxycoccus, Drosera rotundifolia* (round-leaved sundew), *Hypericum virginicum* (marsh St. John's-wort), and *Carex* spp. Herbaceous species occur, in low percentage cover values, throughout the low and tall shrub zones and treed bog zone. *Woodwardia virginica* (Virginia chain fern) is common in the herbaceous layer in the tall shrub zone, and continues to be dominant throughout the swamp thicket-tall shrub zone to the marginal moat.

Fifty-six taxa were found within the herbaceous layer, and were ordered by decreasing frequency-presence index (Table 3). *Cuscuta gronovii* (parasitic dodder), using *Decodon verticillatus* as its host, had the highest importance value (IV 16) in the herbaceous layer at Triangle Lake Bog. Typically, this species is not considered to be a component of bog flora, and was not reported at the other two study areas. Taxa common to all three study areas were among the highest in importance value and frequency-presence index: *Carex canescens* (glaucous sedge), FPI 2566; *Hypericum virginicum,* FPI 2373; *Vaccinium macrocarpon,* FPI 1733; *Woodwardia virginica,* FPI 1653; *Carex trisperma* (three-seeded sedge), FPI 1266; *Lycopus virginicus* (water horehound), FPI 783; *Vaccinium corymbosum,* FPI 783; and *Carex howei* (Howe's Sedge), FPI 383. Fern Lake Bog, the most minerotrophic of the areas (Table 5), contained 49 taxa in the herbaceous layer. Schwintzer (1981), Karlin and Bliss (1984), and Andreas (1989) discussed species richness in fens (minerotrophic peatlands).

Sarracenia purpurea (pitcher-plant), while present at the study areas, did not occur in any quadrat at Fern Lake Bog. This taxon was known historically from Fern Lake Bog (Dachnowski 1912, Medve 1958). Apparently, in the years between 1958 and 1967, *S. purpurea* disappeared from Fern Lake Bog, but in 1967 it was re-introduced. The clumps of pitcher-plants currently found on the southern floating mat at Fern Lake Bog were transplanted there from Triangle Lake Bog by an anonymous botanist.

There is a surprisingly high similarity in dominant taxa in the understory at Little Cedar Bog, Orange County, NY (Lynn 1984) and the present study areas: *Hypericum virginicum, Woodwardia virginica, Rhynchospora alba* (white beak-rush), *Drosera rotundfolia, Sarracenia purpurea,* and *Calla palustris* (wild calla). Lynn (1984) and Dunlop (1987) reported *Peltandra virginica* (arrow-arum) and *Thelypteris palustris* (marsh fern) in mat communities. These taxa occurred near the lake margin at Fern Lake Bog. The emergent plant association described by Dunlop is not present at the study sites, although Dexter (1950) discussed similar emergent vegetation in an alkaline kettle-hole depression lake (pH 6.8 –7.5) in Portage County, OH.

Unlike bog formation in more northern latitudes (Conway 1949, Crow 1969, Heinselman 1970, Schwintzer and Williams 1974), sedges (*Carex* spp.) play little or no role in the formation of the floating mat in Ohio peatlands. Crum (1988) considered sedges to be more important in mat formation in alkaline lakes than in acidic lakes, but at the alkaline lake described by Dexter (1950), *Decodon* is the invading taxa.

According to Schwintzer (1979), *Carex canescens* and

Lycopus uniflorus, included within *L. virginicus* (Cooperrider 1985), can exploit full sunlight in the presence of high water. Elsewhere in Ohio, *C. canescens* increased in percentage cover when the canopy had been removed either manually or by water table fluctuations (Andreas and Host 1983). McGraw (1987) found this species well represented in the seed bank of a bog that had exhibited past disturbances by water table fluctuations (Wieder et al. 1981). In McGraw's study, *C. canescens* exhibited two peaks which may imply two previous episodes of disturbance. *C. canescens* was present in 43% of the plots sampled at Fern Lake Bog, while found in 20% of the plots at Flatiron Lake Bog, and in 14% of the plots at Triangle Lake Bog.

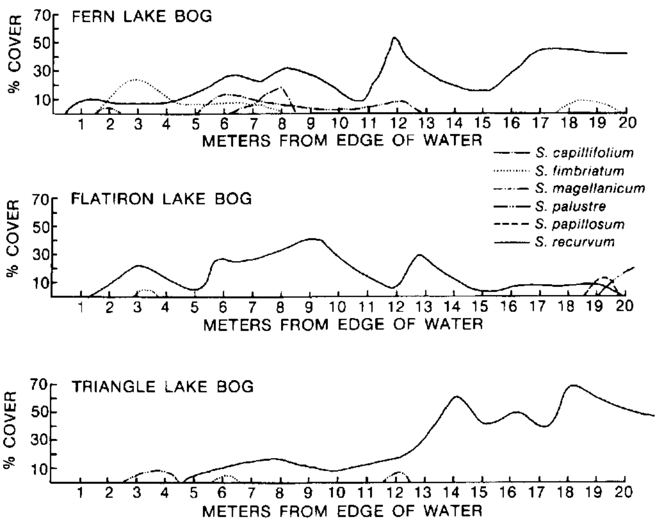

FIGURE 4. Smoothed curves of percentage cover of the major *Sphagnum* species along a transect from open water through 20 m.

GROUND LAYER. For this study, the ground layer included all bryophyte species. Every attempt was made to collect bryophytes within the quadrats. While dominant taxa were recorded, it is possible that some species may have been missed. The *Sphagnum* lawn at the study areas is flat, and without the hummock and hollow microtopography observed in bogs in Michigan and Wisconsin as described by Vitt et al. (1975) and Andrus et al. (1983). *Sphagnum recurvum* (*sensu lato*) dominated the ground layer at all three bogs. Smoothed curve graphs for each peatland depict the sum total percentage cover of the dominant *Sphagnum* species at the study areas in relation to the open water (Fig. 4). In the floating mat (from 1 to 5 m from the open water), *Sphagnum* becomes established around the bases of *Decodon* and *Chamaedaphne*. *S. recurvum* reaches its best development in the shaded grounded mat and treed bog zone. This species has a high shade tolerance, and generally forms loose carpets at water level and near the transition zone between bog and bog forest in ombrotrophic to weakly minerotrophic peatlands (Vitt and Slack 1975, Crum 1983, 1988). At each area, the percentage cover of this taxon increased in the tall shrub zone, and *Carex trisperma* was often associated with *S. recurvum*. According to Vitt and Slack (1975), *S. recurvum* has a wide pH tolerance, but only becomes dominant under conditions of low pH and Ca and Mg concentrations.

At Fern Lake Bog, *Sphagnum capillifolium* and *S. fimbriatum* occurred in wet areas in the floating mat, but percentage cover was low. These two taxa typically grow in water among heath vegetation (Crum 1983). *S. magellanicum* was found within the transects at Flatiron Lake Bog, where it was abundant in open area about 20-22 m from the open lake. *Aulacomnium palustre* occurred repeatedly on the bases of shrubs throughout the transects at all three study areas. Other *Sphagnum* and bryophyte taxa are listed in Table 3. Additional bryophyte taxa, including *Dicranum polysetum, Leucobryum glaucum,* and *Polytrichum commune* were collected from organic hummocks in the swamp thicket-tall shrub zone between the moat and the treed bog zone.

Similar floristic and water chemistry data are available for three other northeastern Ohio peatlands. Data were collected by Andreas and Host (1983) for Silica Sand Quarry Bog, Portage County, a peatland that developed on the floor of an abandoned sandstone quarry in less than 70 years. The flora of Browns Lake Bog, Wayne County, was determined by Andreas (1980) and Whitney (1983), and the flora of Jackson Fen, Stark County, was surveyed by Andreas and Knoop in 1987 (unpublished). Water chemistry characteristics for Browns Lake Bog and Jackson Fen were determined by Bryan and Andreas (1986). Browns Lake Bog is weakly minerotrophic with the following values: pH, 4.0 - 4.6; conductivity, 26.0 μmhos/cm ± 5.0; Ca, 4.7 mg/1 ± 0.7; and Mg, 1.9 mg/1 ± 0.6. Jackson Fen is strongly minerotrophic with the following values: pH, 7.4 - 7.8; conductivity, 747 μmhos/cm ± 88; Ca, 87.0 mg/1 ± 41; and Mg, 51.1 mg/1 ± 23.

Similarity indices were used to compare the flora of six northeastern Ohio peatlands (Table 4). Curtis (1959) presented a similarity index of 0.64 as typical for communities under the same general conditions in a small geographical area. The highest index of similarity is between Flatiron Lake Bog and Triangle Lake Bog (0.72). These two peatlands also are most alike in terms of water chemistry values (Table 5). Fern Lake Bog and Triangle Lake Bog have a similarity index of 0.67. Fern Lake Bog and Browns Lake Bog have a similarity index of 0.55.

TABLE 4

Comparison of index of similarity for six northeastern Ohio peatlands.

Fern Lake, Geauga County, Ohio					
0.59	Flatiron Lake, Portage County, Ohio				
0.67	0.72	Triangle Lake, Portage County, Ohio			
0.41	0.39	0.42	Silica Sand Quarry, Portage County, Ohio		
0.55	0.40	0.45	0.28	Browns Lake Bog, Wayne County, Ohio	
0.21	0.13	0.17	0.14	0.18	Jackson Fen, Stark County, Ohio

TABLE 5

Chemical and physical characteristics of open lake and Sphagnum *mat at study sites during May - September, 1985. Values for conductivity, temperature, Ca and Mg are expressed as means ± 1 SD.*

Natural Area	pH at 20°C	Conductivity µmhos/cm at 25°C	Temperature °C	Ca mg/1	Mg mg/1
Fern Lake Bog					
Lake	6.3 – 7.3	48.0 ± 9.6	22.8 ± 3.3	6.0 ± 1.3	2.6 ± 0.7
Bog mat	4.0 – 5.6	47.0 ± 11.8	22.6 ± 3.2	4.5 ± 1.7	1.8 ± 1.0
Flatiron Lake Bog					
Lake	4.1 – 4.3	44.0 ± 2.7	18.2 ± 2.8	2.8 ± 0.8	1.2 ± 0.4
Bog mat	3.5 – 4.2	45.7 ± 14.9	18.8 ± 2.4	2.9 ± 0.5	1.3 ± 0.4
Triangle Lake Bog					
Lake	4.0 – 5.1	33.0 ± 8.7	18.8 ± 4.1	2.8 ± 0.8	1.7 ± 0.3
Bog mat	3.5 – 4.0	48.0 ± 19.2	17.9 ± 3.9	2.9 ± 0.5	1.2 ± 0.4

When comparing Jackson Fen to the study sites, the indices are low. This reflects differences between "bogs" and "fens" within a small geographical area. Schwintzer (1978a) found an average similarity index of 0.47 when comparing six northern lower Michigan bogs. The average similarity index for the three study sites is 0.66.

Water Chemistry

Water chemistry variables were measured from samples taken from the open lake and floating bog mat at each study area (Table 5). Factors affecting water chemistry of a wetland include: 1) the chemical composition of rain; 2) the bedrock geology of the catchment, especially for all surface and sub-surface water movement; 3) the topography of the catchment and its drainage systems; 4) the climate of the region as it affects physical weathering; and 5) biotic components such as aquatic and terrestrial plants and their rate of decomposition (Moore and Bellamy 1974).

Sphagnum modifies water by reducing its pH (Clymo 1964, Moore and Bellamy 1974, Glime et al. 1982). Water samples taken from the floating mat are consistently more acidic than water from the open lake. The impact of this phenomenon was less at Triangle Lake Bog and Flatiron Lake Bog, where lake waters already had low pH (Table 5), but greater at Fern Lake Bog, where the lake water is

TABLE 6

Water chemistry characteristics from bogs in MI, MN, NY-NJ, OH and WI. Values are from the following sources: MI, MN and WI (Schwintzer and Tomberlin 1982); NJ-NY (Lynn and Karlin 1985); and OH (present study).

State	Description	pH	Conductivity µmhos/cm at 25°C	Alkalinity mg/1 as $CaCO_3$	Ca m/1
MI	depression or valley bog	3.8-4.3	48-66	None	1.2-3.7
MN	semiraised or raised bog	3.2-3.8	35-78[1]	None	0.6-3.5
NJ-NY	low-shrub bog adjacent lake	3.2-4.2 3.3-6.0	-	trace-12	trace-3.2
OH	low shrub bog adjacent lake	3.5-5.6 4.0-7.3	45-48	none to 2.6[2]	2.9-4.5
WI	moss peat: black spruce-tamarack muskeg	3.5-4.2	50-61	None	-

[1] Conductivity at 20°C
[2] from Bryan and Andreas (1986)

more alkaline. Williams and McCleary (1982) indicate two sources of surface run-off, through intermittent drainage channels from agricultural fields, into the depression surrounding Fern Lake Bog. These potential sources for nutrient loading may be affecting the water chemistry of Fern Lake Bog.

Karlin and Bliss (1984) warned that peatland classification based only on water chemistry ignored the possibility of a pronounced difference in the chemical environment of the hummocks. At the three study areas, the mat is more or less flat and hollow-hummock topography does not occur. Although there may be certain places where *Sphagnum* rises above the influence of the surface water, the point when the bog becomes ombrogenous, such areas were not observed within the transects examined during this study.

The pH, conductivity, calcium ions and alkalinity of bogs from New Jersey and New York (Lynn and Karlin 1985), Minnesota, Wisconsin, and Michigan (Schwintzer and Tomberlin 1982) were compared to the results from this study (Table 6). Values for pH and Ca (mg/1) are similar to those reported for seven low-shrub bogs in New Jersey and New York (Lynn and Karlin 1985), where pH of the lakes range from 3.3 - 6.0, and pH of the mat range from 3.2 - 4.2. Calcium values reported by Lynn and Karlin (1985) range from a trace to 3.2 mg/1. The mat at Fern Lake Bog has Ca values slightly higher than the other areas. Fern Lake Bog was the only study area in which alkalinity, measured as mg/1 $CaCO_3$, was detected. The values here are much lower (2.6 vs. 12 mg/1) than the range cited by Lynn and Karlin (1985).

Based on pH, conductivity, Ca and Mg ions, there exists a continuum within peatlands. In ombrotrophic peatlands, nutrients and water primarily are brought into the system through rain, and values for the above characteristics are at the low end of the continuum. In weakly, moderately, and strongly minerotrophic peatlands, nutrients and water enter the system primarily through ground water and run-off, and values for the above characteristics range to the high end of the continuum. In reviewing the literature (Heinselman 1970, Moore and Bellamy 1974, Larsen 1982, Karlin and Bliss 1984), it is possible to make delineations which separate peatlands into five broad categories (Table 7). It should be noted that these delineations are arbitrary subdivisions of a continuum, and that this continuum varies within microhabitats within any peatland. There is no general consensus in the exact ranges to be used.

Using values presented in this study (Table 5), Fern Lake Bog is classified as a weakly minerotrophic peatland. Floristically, it has a higher number of species within the sampled area than do Flatiron Lake Bog or Triangle Lake Bog. Flatiron Lake Bog and Triangle Lake Bog are classified as semi-ombrotrophic. The Michigan bogs discussed by Schwintzer and Tomberlin (1982) would be classified as semi-ombrotrophic to weakly minerotrophic, those from Wisconsin, weakly minerotrophic; Minnesota, ombrotrophic; and New Jersey semi-ombrotrophic to weakly minerotrophic (Table 6).

Ohio peatlands surveyed to date show indications of influence from ground water and, as a result, no strictly ombrotrophic bogs occur within the state. Ohio peatlands develop in relatively small organic depressions where nutrient run-off from surrounding uplands influences the water throughout the depression. This is especially true at Fern Lake Bog and is reflected in the change in pH values between the open lake and bog mat, and in the presence of $CaCO_3$. Extensive vertical zonation of bryophytes forming hummocks was not observed. Thus, few areas are raised above the influence of the water table, and those Ohio peatlands included in this study do not show hummock-hollow topography.

Bogs typically are characterized by low species richness. A total of 56 vascular plant taxa in 39 families were found within the areas surveyed: 54 taxa, Fern Lake Bog; 29, Triangle Lake Bog; and 20, Flatiron Lake Bog. Wheeler et al. (1983) found 23 vascular plant taxa in ombrotrophic sites and 195 vascular plant taxa in poor and rich fen sites within the Red Lake Peatland in north-central Minnesota. In that study, 23% of the peatland flora were members of the Cyperaceae, whereas in our study, 14% of the flora are members of the Cyperaceae.

The shrub layer is most consistent in the three basin-type bogs. Seven of the 14 taxa in the shrub layer are found

TABLE 7

Classification of peatlands based on ranges in water chemistry characteristics. Summarized from Heinselman (1970); Moore and Bellamy (1974); Larsen (1982); and Karlin and Bliss (1984).

	pH	Conductivity µmhos/cm	Ca mg/1	Mg mg/1
ombrotrophic	3.2 – 3.8	12 – 27	0.6 – 2.1	0 – 0.2
semi-ombrotrophic	3.7 – 4.2	20 – 50	1.5 – 3.5	0.2 – 1.0
weakly minerotrophic	4.0 – 6.0	25 – 75	3.5 – 12	1.0 – 1.5
moderately minerotrophic	5.8 – 7.0	70 – 120	10.0 – 30	1.1 – 2.8
strongly minerotrophic	7.0 – 8.0	> 120	> 30	> 2.8

at all three sites. These taxa are also the most common elements at the sites, with highest percent cover, frequency, and FPI (Table 3). *Chamaedaphne calyculata* and *Decodon verticillata* dominate the low shrub floating mat, while *Vaccinium corymbosum* and *Gaylussacia baccata* dominate the grounded mat. Only eight of the 56 vascular plant taxa found in the herbaceous layer occur at all three sites. Five of the eight taxa have frequency-presence indices above 800. Three of 13 taxa found in the bryophyte layer are common to all three sites.

Basin-type bogs studied here show the same plant association zonations mentioned elsewhere in the literature. These areas are most similar to those described in New York and New Jersey (Lynn 1984, Lynn and Karlin 1985), which are also of the same geologic age and latitude.

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The 1989 Paper of the Year Award

was presented at the 99th Annual Meeting
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Dr. William J. Mitsch

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for their paper:

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