8-1-1991

TB146: The Eccentric Bogs of Maine: A Rare Wetland Type in the United States

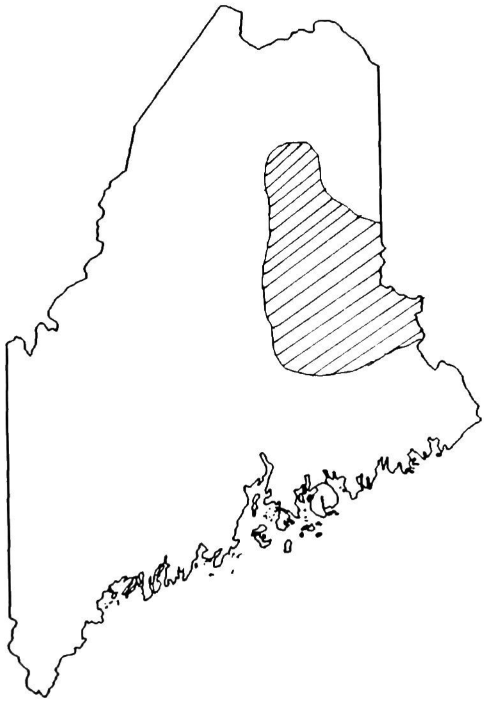
Ronald B. Davis

Dennis S. Anderson

ISSN: 0734–9556

The Eccentric Bogs of Maine:

A Rare Wetland Type in the United States



Ronald B. Davis

and

Dennis S. Anderson

Technical Bulletin 146

UNIVERSITY OF MAINE

August 1991

MAINE AGRICULTURAL EXPERIMENT STATION

The Eccentric Bogs of Maine: A Rare Wetland Type in the United States

Ronald B. Davis
Professor

and

Dennis S. Anderson
Assistant Scientist

Department of Plant Biology and Pathology
and
Institute for Quaternary Studies
University of Maine
Orono, Maine 04469

Maine State Planning Office, Critical Areas Program,
Planning Report 93.

CONTENTS

TABLES

FIGURES

ACKNOWLEDGMENTS

Numerous persons and several agencies helped to make this work possible. For laboratory and field assistance we thank Celeste Doyle, Courtney Eastman, Anne Frazer, Timothy Kluge, Lisa Miller, Annie Narahara, Jeremy Perkins, Thomas Rhodes, Jennifer Ruffing, Michael Senatore, and Klara Varga. Jan Janssens identified many of the bryophyte specimens. Chemical analyses were made by Steve Kahl and other personnel of the University of Maine Watershed Manipulation Project and by Bruce Hoskins and other personnel of the Maine Agricultural Experiment Station Analytical Laboratory. Fengsheng Hu carried out the peat stratigraphic analyses. The Maine Geological Survey provided access to its air photo collection, and the University of Maine Department of Survey Engineering allowed use of its digitizer. Richard S. Clymo, David R. Foster, Nils Malmer, Harry R. Tyler Jr., and Ian A. Worley provided helpful reviews of the manuscript.

We gratefully acknowledge funding from the Maine Agricultural Experiment Station (1987 ff.), the Maine Department of Conservation (1981–1983), and the Critical Areas Program of the Maine State Planning Office (1987–1988). The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the University of Maine Environmental Studies Center. The contents of this publication do not necessarily reflect the views and policies of the Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.

ABSTRACT

Eccentric bogs are rare in the United States, known only from northeastern Maine where 22 eccentric bogs have been confirmed out of an estimated total of 35. Fifteen were field studied in 1987; two in earlier projects. The bog units are part of peatland complexes dominated by gymnosperm wooded fens. These complexes are usually part of larger multiple-unit peatlands. The 17 mapped complexes range from 366 to 4130 acres (148–1671 ha) each. Bog units (the "bog proper" = ombrotrophic area) cover about half or less than half the area of the complex. Bog units occur on gentle side slopes of valleys. The bog-unit surface slopes in the same direction, and has a cross-slope microtopographic pattern of alternating ridges and troughs (some with pools). The upslope end abuts mineral upland, the downslope end borders fen which continues in the valley bottom to a stream or lake.

Most of the complexes are underlain by glaciolacustrine clay-silt that is usually topped by humic lake sediment (dy), above which is peat. Developmental sequences vary, the most common being lake to open fen, to semi-wooded fen, to wooded fen or semi-wooded bog. Also, open fen and semi-open fen stages commonly develop into open bog. Maximum peat depth per complex ranges from 5.2 to 8.2 m.

A total of 240 taxa of vascular plants, bryophytes, and lichens were tallied in 1987 at 15 complexes, averaging 79 taxa per complex in an average 8.4-hour survey. None of these taxa is rare; many are common and widespread at oligotrophic and acidic peatlands in Maine. Twenty-two vegetation types were distinguished, comprised of four major groups in a continuum: (1) moss lawns and mud bottoms of the bog proper; (2) shrub heaths, wooded shrub heaths, and forested bog of the bog proper, together with extreme poor open fen; (3) black spruce/*Sphagnum*/Ericaceae fens; and (4) alder/winterberry/fern fens.

Peat interstitial waters are generally very dilute and acidic, with all but three of the 77 samples being similar to published values for bog, extreme poor fen, and poor fen, and the three other samples to the poor range of intermediate fen. Canonical correspondence analysis indicates that the primary vegetational continuum (1–4) is along a restricted chemical trophic gradient, very oligotrophic to oligo-mesotrophic.

The 17 peatlands studied in the field include the most exemplary eccentric bogs in Maine. Based on an objective method of evaluation, ten of the 17 are recommended to the Maine Critical Areas Program for designation as Critical Areas. This high proportion (10/17) of study sites results from the great rarity of this geomorphic/hydrologic peatland type in the United States. Four of the complexes are most highly recommended: Peatland at Cold Stream, Peatland at Macwaho

INTRODUCTION

Eccentric bogs were first reported for North America by Davis et al. (1983) who called them "eccentric dome peatlands" and mapped the locations of eight of them in Maine. As this wetland type had not been reported from and is probably absent in other U.S. states[1], and appeared to be rare or infrequent in Maine, further work was initiated in 1987 to determine the abundance and distribution of the type in Maine and to study its form, origins and development, vegetation, and chemistry. The results of that work are reported here, with recommendations that some of Maine's eccentric bogs be designated as Critical Areas.

The specific objectives of this project were to:

1. map the distribution in Maine of eccentric bogs;
2. map the surface physical features and vegetation of a large sample of Maine's eccentric bogs;
3. determine for these bogs the
   — vascular plant, bryophyte, and lichen flora,
   — types and structure of vegetation,
   — peat interstitial water (piw) chemistry,
   — relationships between vegetation-flora and piw chemistry,
   — subsurface features relating to origins and development (peat stratigraphy); and
4. evaluate the bogs for their unique and exemplary characteristics, and recommend certain of them to the Maine Critical Areas Program for designation as Critical Areas (worthy of protection as natural areas).

[1]Information on Alaska that would indicate presence or absence of eccentric bogs there has not been found.

BACKGROUND

Eccentric Bogs are True Bogs. What is a True Bog?

A true bog is a peat-containing wetland, a major part of whose growing surface receives no inputs from underlying or adjacent mineral soils. Instead, the plants on that part rely on wet and dry inputs from the atmosphere to supply their mineral needs. These plants are said to grow under ombrotrophic conditions (Gk. *ombros* = rain; Gk. *trophe* = food); that is, they are fed by the atmosphere. Eccentric bogs are true bogs.

Input rates of mineral nutrients from the atmosphere are generally very low and place limits on plant productivity in ombrotrophic systems. An important mechanism for maintaining productivity under such circumstances is tight recycling of nutrients (Rydin and Clymo 1989). Nevertheless, productivity in ombrotrophic peatlands is generally low compared to other types of wetlands (Bradbury and Grace 1983).

The low flux of minerals to ombrotrophic peatlands not only renders them infertile (oligotrophic), but also allows for the development of a highly acidic condition. Most mineral soils have the capacity to neutralize the acids produced *in situ* (by cation exchange, respiration, and decomposition of organic matter) as well as the acids deposited from the atmosphere (including acidic air pollutants). This capacity is largely absent from ombrogenous organic soil (bog upper peat). While mineral soils commonly have pH ranging from 5 to 8, bog upper peats usually have pH of about 4 (Shotyk 1988). Only a limited number of plant species can thrive under these infertile, acidic conditions, most notably certain species of *Sphagnum* (peat moss), species of *Eriophorum* (cotton "grass"), and members of the Ericaceae (heath family).

Over the approximately twelve millennia since deglaciation, the remains of plants have accumulated to form thick layers of peat in most of Maine's non-tidal wetlands. Most of these peaty wetlands (peatlands or mires) are minerotrophic, not true bogs, because the accumulation of peat has been insufficient to raise the growing surface above waters that flow through mineral substrates. These minerotrophic peatlands, with flat or gently concave surfaces, are properly called fens despite the fact that many of them in Maine bear the name bog on USGS maps (e.g., Alton Bog: a poor fen) (Davis and Anderson in prep. a). In true bogs, a major part of the surface has been built up higher and has become gently convex, placing that surface out of contact with solute-rich waters. The differences between fens and bogs are summarized in Table 1. Henceforth in this report, the term bog (alone) will be used in the strict sense to designate a true or raised bog.

Table 1. General features of fens and bogs.

Features	Fens	Bogs
Geographic distribution	worldwide, moist locations	primarily boreal, moist locations
Abundance	numerous	less numerous
Surface topography	concave/flat	convex (raised)
Peat depth	shallow	deep
pH	4–9	3.5–4.5
Nutrient source	ground water and atmosphere	atmosphere
Productivity	low - high	low
Decomposition	relatively high	low
Floristic diversity	low - high	low

The continuing build-up of peat to form a bog depends on environmental conditions that (1) reduce decomposition of organic matter and (2) allow for continued plant (and peat) production on a raised surface. Decomposition is reduced by a climate that maintains low temperature in the peat mass and by anoxic conditions in the water-logged mass due to microorganisms at the top of the waterlogged zone consuming oxygen faster than it can be replaced by diffusion from the air. (Water in the peat does not circulate to any extent, unlike most lakes.) The second requirement—conditions suitable for continuing growth of peat-forming plants—is mainly a problem of maintaining enough water at rooting depths just under the raised surface. This depends on an excess of precipitation over evapotranspiration for the year and a moist growing season.

The water-saturated peat near the surface of bogs contains well over 90% water (Tolonen et al. 1988). To maintain this condition at a raised surface, the peat must be able to hold water above the surrounding water table. Although capillary forces in peat account for a small part (<~0.5 m) of that head of water (Granlund 1932; Clymo in press), the main factors are a very slow downward drainage (low hydraulic conductivity of the peat mass) combined with an exces of precipitation over evapotranspiration that is sufficient to compensate for drainage (Ingram 1983).

The water at rooting depths in bogs is not drawn up from the base of the peat where mineral layers occur. Rather, the bog's surface and near-surface water is supplied from the atmosphere. Flow is strongest within the relatively porous conductive upper part of the peat—the oxygenated acrotelm, which varies in depth mostly from ~0.1 to ~1.0 m. While there is a downward flow vector from the acrotelm into the underlying anoxic peat (the catotelm), the major route for drainage of excess water in the acrotelm is sideways along the gentle slopes of the bog to surrounding, low-lying minerotrophic wetlands (Ingram 1983).

Underlying the acrotelm is the water-saturated catotelm, which can be several meters deep. The catotelm is devoid of free oxygen, which retards the decomposition of plant remains. If the production of new plant material exceeds decomposition in the entire peat mass (acrotelm + catotelm), the mass continues to increase and the bog "grows" (Clymo 1984).

The presence of bogs requires that long ago there were suitable wet places on the landscape for peatlands to start developing and that there has been a sufficiently long period of suitable climate for the early stages (fens) to develop into bogs. Research in Maine (Tolonen et al. 1988; Hu 1990; Hu and Davis in prep.) has shown that it has taken thousands of years since deglaciation for fens to thicken into bogs. That bogs have developed at all in Maine indicates that the climate has been cool and moist enough to retard decay and to maintain a wet rooting zone on raised peatland surfaces. In eastern North America since the last glacial period, these conditions have not been present long enough for bog development south of Maine. In Maine bogs now reach their southern limit in eastern North America (Davis 1989a).

The "healthy" appearance of Maine's present bog vegetation may suggest that Maine's climate continues to be suitable for bogs. Appearances, however, can be misleading, for, as implied earlier, the long-term maintenance of a raised peat mass is not a function of plant production alone, but rather of decay not exceeding production of peat. A warming of Maine's climate as a result of the "greenhouse effect" may result in cessation of bog formation (Gorham 1988, 1991), at least in the more southern part of the state. The increased temperature may lead to decay exceeding gross production of organic matter, so that peat accumulation ceases or becomes negative even though production continues. Increased temperature would degrade bogs also by drying and the resulting oxygenation of upper peats, and possibly by increased fire frequency.

Eccentric Bogs are Special Types of Bogs

Eccentric bogs differ from other bogs (Table 2) in Maine in that they slope mainly in one direction, and they occur on the sides of valleys. The upslope end of the bog abuts or nearly abuts mineral upland. The downslope end borders an unpatterned fen which, in turn, borders a stream or lake in the valley bottom. The bog slope usually has a surface pattern of cross-slope alternating, near-parallel ridges and troughs (Fig. 1; e.g., Coffin Bog: Fig. 23). In many cases, the troughs contain secondary pools[2]. Downslope flow of surface and near-surface water is perpendicular to the ridges and troughs. Gaps may be present through the ridges, facilitating the passage of surface water. The main slope can depart from unidirectional to the extent that the bog is fan-shaped, with the highest point at the "rivet" or "handle attachment" of the fan, in which case the ridges and troughs are arranged in arcs (e.g., Peatland at Cold Stream: Fig. 25). In some cases, a distinct cupola is present near the upper end of the bog (e.g., Peatland at Smith Brook Deadwater: Fig. 3; Perkins 1985). A diagramatic representation of a typical eccentric bog, and diagrams of other peatland types for comparison are given in Figure 1.

It is important to point out that domed concentric bogs whose highest point is off-center and whose concentricity is skewed to one side are not eccentric bogs. Despite the off-center position of the dome on these peatlands, they slope down appreciably in all directions from their highest point, the highest point of the peatland does not come near to abutting upland, and the underlying mineral substrate does not slope appreciably in a single direction (as on the side of a valley). An example of a concentric domed bog with highest point off-center is Thousand Acre Heath T3R1 in Maine, which was described by Worley (1981a) as having "eccentric patterning" of ridges and troughs (some with pools).

The upslope part of an eccentric bog is *relatively* dry on the surface. Down the main slope, the surface becomes wetter, particularly in the troughs of the patterned part of the bog. In Maine, the pattern usually consists of peat ridges with shrub-heath or wooded shrub-heath vegetation, or both, alternating with troughs containing either or both secondary pools and wet *Sphagnum* moss lawns (usually with some sedges and dwarf shrubs).

From what has been said about eccentric bogs, it will be apparent that "not all of a bog is a bog". All kinds of bogs (eccentric, concentric, plateau) always have peripheral low-lying areas of minerotrophic peatland (fen). The vegetation of these more fertile areas differs from the ombrotrophic part (herein called the bog proper) and is usually richer in species. It is also apparent that even the bog proper has areas of differing vegetation (e.g., on ridges and in troughs of eccentric bogs). For these reasons, the entire peatland, containing but not limited to the bog proper, is considered to be a peatland complex (= mire complex). Despite the ever-present fen areas of these complexes, the entire complex is usually called a bog, for example, the eccentric Big Bog. The surface features of eccentric

[2]By "secondary" is meant that the pool formed on the peat surface. It is not a remnant of a primary body of water that existed at the outset of peatland development.

Table 2. Maine peatland types, number of observed sites and, in parentheses, an estimate of the total number of sites, and distribution in the state. With the exception of Type 1, all the types are known to occur in various combinations in multiple-unit peatlands (see text footnote 3). (From Davis 1989a).

Type No.	Name	Number* obs.(est.)	Maine** region
I.	Shallow (peat <~0.7 m deep), small (<0.4 ha), on subalpine/alpine and marine-shoreline slopes		
1	Maritime-slope and subalpine/ alpine-slope peatland	19 (<~50)	3–5@ 9B
II.	Other peatlands; not located on slopes as I.; variable peat depths, generally >0.7 m deep at some place(s); variable size (<0.1–>2000ha)		
	A. Geogenous*** (Fens)		
2	Unpatterned fen**** in stream valley or drainage way	>200 (>~1000)	all#
3	Unpatterned fen**** in open basin	>200 (>~1000)	all#
4	Unpatterned fen**** in closed basin	>100 (>~500)	all#^
5	Ribbed fen	50 (~60)	4–7
	B. Ombrogenous (Bogs)		
6	Relatively flat inland bog (distinct from No. 9), without concentric or eccentric pattern		
	(a) without secondary pools	154 (~200)	all#^
	(b) with secondary pools	24 (~50)	all#^~
7	Eccentric bog	22 (<~35)	7!
8	Domed bog with concentric pattern		
	(a) without secondary pools	34 (~50)	7–9~&
	(b) with secondary pools	28 (~30)	7–9~&
9	Coastal bog (relatively flat, or plateau)	~100	9B

*See Davis (1989a) for statement on confidence in estimates. Based on Worley (1980, 1981b), Davis et al. (1983), Widoff and Ruffing (1984), Sorenson (1986), Davis and Anderson (unpubl. data). Estimates of type 4 are based on sites of at least 2 acres (~1 ha) each.

**Region numbers from Figure 2: @ = above 3500 ft (1067 m) altitude, or at immediate seashore east of Frenchman Bay; # = less common in mountainous areas; ^ = less common in southwest lowlands (for raised bogs, much less common there); ~ = mostly east of Bangor; ! = one known site in region 4 and one known site in region 8; & = possibly small number of sites in southern parts of regions 4 and 5.

***Includes transitional type of Davis et al. (1983).

****Includes wooded, semi-wooded, and unwooded fens.

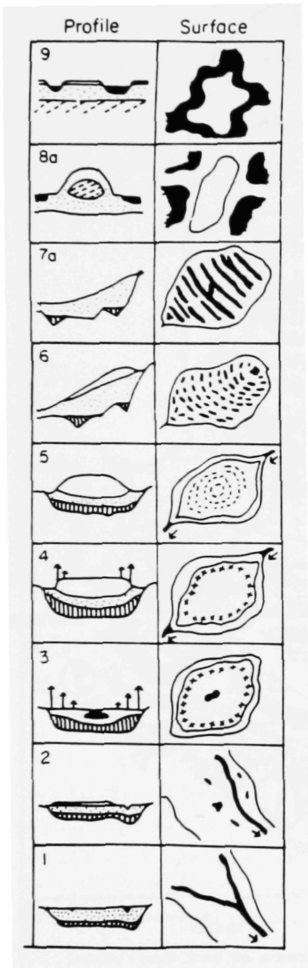


Figure 1. Profiles and surface features of the main types of peatlands in Europe, arranged from top to bottom in relation to the north to south distribution of types. These types are also present in glaciated eastern North America from ca. 60° to ca. 40° N lat, in roughly the same north to south sequence as in Europe (Glaser and Janssens 1986; NWWG 1988; Davis 1989a). The diagrams typifying the European eccentric bog type are entirely appropriate for the eccentric bog type in Maine. For the profiles, ice is diagonally hatched, primary peat is vertically hatched, secondary peat stippled, and tertiary peat lacks pattern. See text of this report and/or Moore and Bellamy (1974) for description of the three peat types. Slopes are greatly exaggerated. For surfaces, open water is given in black, flow by arrows, and trees by x's. Reprinted, with permission, from Moore and Bellamy (1974:30). We have modified type names for this report.

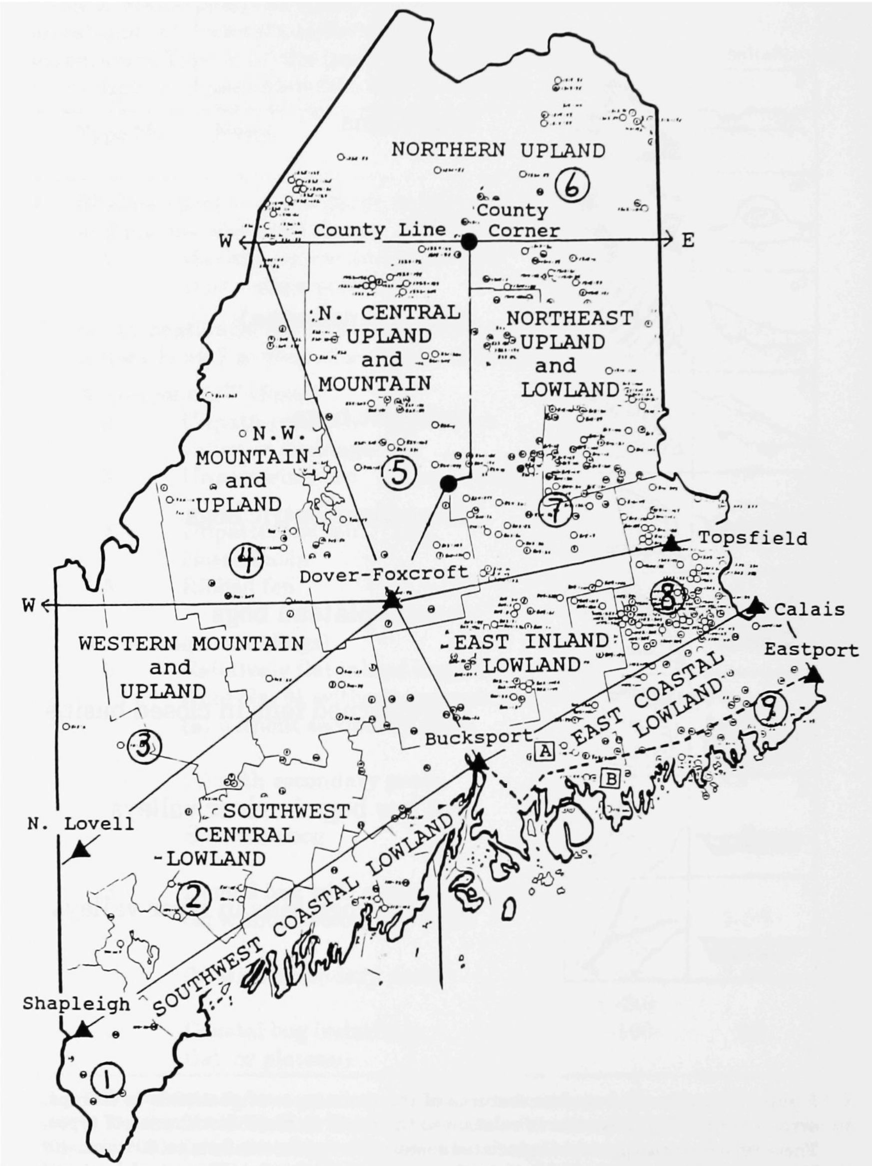


Figure 2. Interim regions for describing the distribution of Maine peatland types and for the evaluation of the ecological significance of Maine peatlands on an in-state regional level. Each region has an identification number corresponding to the numbers in Table 2. From Davis (1989 a & b).

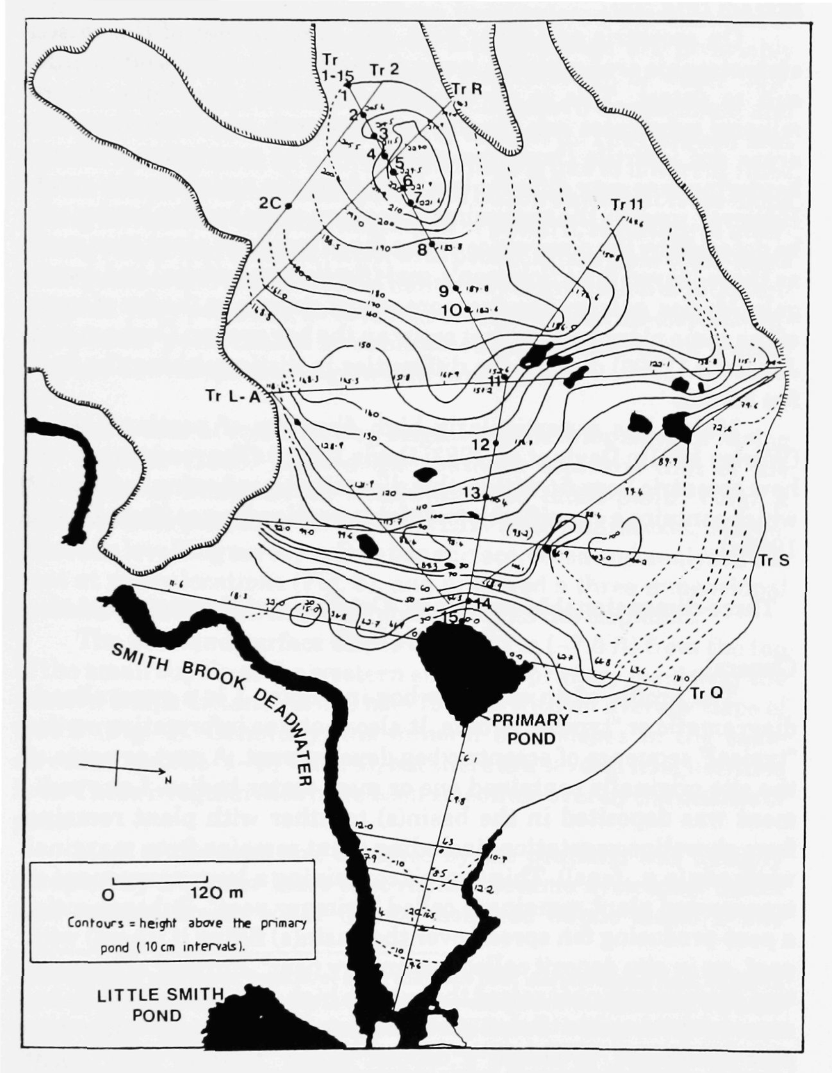


Figure 3. Surface topography of the south unit of the multiple-unit Peatlands at Smith Brook Deadwater and Little Smith Pond. Dashed portions of contour lines are conjectural (based on surface drainage features/patterns and extrapolation). Open water is given in black. Transect lines, along which cores of peat were collected for study of peatland development, are shown. Only transect 1–15 is labelled with core sites (little black circles). See Figure 4 for peat profiles along that transect. From Perkins (1985).

bogs are illustrated at the end of the body of this report; see particularly Big Bog (Fig. 21), Coffin Bog (Fig. 23), and Peatland at Cold Stream (Fig. 25).

On eccentric and other bogs, the exact border of the raised ombrotrophic area with the lower minerotrophic area is often difficult to detect. This is particularly a problem in Maine where mineral substrates are usually nutrient-poor, and downslope fen areas are infertile ("extreme poor fen"). The vegetation of these bordering fens may differ only a little from the ombrotrophic area. However, usually the approximate position of the bog/fen border can be detected by the occurrence on the fen of indicator plant taxa such as three-leaved false Solomon's-seal (*Smilacina trifolia*) and sweet gale (*Myrica gale*) and by the more robust stature on the fen of some of the same plant species that occur on the bog proper. Gorham and Janssens (1990) discuss the difficulties in distinguishing the bog/fen border.

Maine has a particularly high diversity of peatland types (Worley 1981b; Davis et al. 1983; Davis 1989a). The reader may see how eccentric bogs fit within this diversity by referring to Table 2 which contains a classification of Maine peatland types (from Davis, 1989a).

Three-dimensional Morphology, Origins, and Development of Eccentric Bogs

General

The profile of an eccentric bog in Figure 1 is a generalized-diagramatic or "typical" profile. It also contains information on the "typical" sequence of eccentric bog development. A part or parts of the site originally contained one or more water bodies. Lake sediment was deposited in the basin(s) together with plant remains from shoreline vegetation (including plant remains from marginal wetlands [e.g., fens]). This deposit containing a large component of transported plant remains is called "primary peat". Subsequently, a peat-producing fen spread over the basin(s) filling it (them) with peat, an *in situ* deposit called "secondary peat". Further accumulation of secondary peat raised the surface high enough so it finally became ombrotrophic. Subsequent accumulation, under ombrotrophic conditions, produced a deposit called "tertiary peat" (peat terminology from Moore and Bellamy 1974). At some time in the development of eccentric bog units, any initially separate basins of peat accumulation coalesced by the lateral spread of peat. The entire process of eccentric bog development takes thousands of years.

Numerous hypotheses have been published to explain the development of surface patterns on fens and bogs. Foster et al. (1983) and Foster et al. (1988) and others have pointed out that linear patterns of ridges and troughs on fens and bogs are invariably oriented perpendicular to the slope and direction of water flow. Those authors reviewed the literature on pattern development and considered the various hypotheses to explain it. They argued that pattern development on both fens and bogs is due to different rates of peat accumulation in hummocks and hollows and that cross-slope (along elevational contour) alignment of pattern, resulting in alternating ridges and troughs (often with pools), arises from cross-slope enlargement and coalescence of hollows by degradation of intervening peat. They point out, as does Ingram (1983), that up-slope/downslope linear pools cannot be maintained (apart from water tracks) because downslope drainage would take place.

A specific case of eccentric bog origins and development in Maine

Perkins (1985) studied the southern eccentric unit of the Peatlands at Smith Brook Deadwater and Little Smith Pond, a multiple-unit peatland[3] at T1 R8 WELS near Millinocket, Maine. He made levelling surveys of the bog surface, cored and analyzed the peat at many locations (Fig. 3), and prepared a three-dimensional reconstruction of the bog and interpreted its development.

The peatland surface slopes down 2.3 m (~7.5 ft) from the top of the small cupola at the western end to the primary pond near the eastern end, a distance of 600 m (~1985 ft) with an average slope of 0.39% (Fig. 3). Generally, the mineral base slopes in the same direction (profile "1–15": Fig. 4), but there are several irregularities in it. These irregularities have been smoothed over by the mantle of peat.

Most of the area now occupied by the peatland was initially occupied by a lake or lakes that rapidly became dystrophic (lakes that contain brown water due to dissolved humic matter). The

[3]Multiple-unit peatlands "consist of more than one peat morphological unit, either of the same type or of differing types in differing combinations....at least one of the units must be other than a coalesced (*sensu* Cameron 1975) raised bog unit....Multiple-unit peatlands were called peatland 'complexes' by Davis et al. (1983). To avoid confusion with the concept of the mire complex (described above), the term 'complex' *sensu* Davis et al. (1983) has been abandoned" (Davis, 1989a:21, 25). A "peat morphological unit" is a major section of a peatland originating from a separate peat nucleus, which may have developed in a separate geomorphic basin or subbasin, or a different part of the same basin, and which remains distinguishable (not completely coalesced) by surface features from adjacent units. While the units of a multiple-unit peatland are adjacent, they need not be completely or directly contiguous. Units may be entirely separated from each other by streams, or partly separated by upland islands.

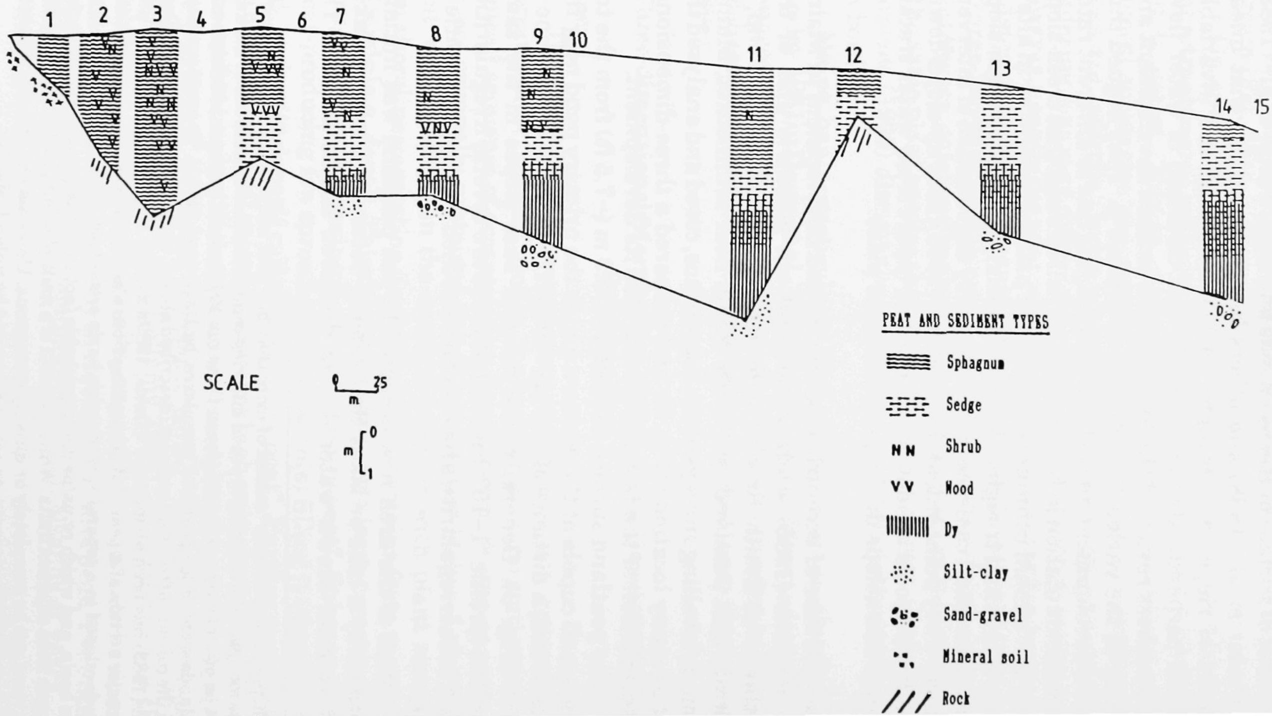


Figure 4. Transect of peat profiles based on cores 1–15 at south unit of Peatlands at Smith Brook Deadwater and Little Smith Pond. See Figure 3 for location of transect on the peatland. See text for description of peatland development based on these data.

lake(s) left a deposit of dy—a lake sediment formed under dystrophic conditions and consisting of highly humified organic matter, colloidal and jelly-like, with abundant aquatic microfossils, and only small amounts of clastic mineral matter. The lake(s) was (were) gradually obliterated by sedimentation, at first by dy, and then by dy mixed with coarse organic remains of wetland plants that were transported from the shallows. This led to enough shallowing of the deepest areas to allow for colonization by sedges and other wetland plants. The colonization is evidenced by fibrous peat consisting mostly of *in situ* remains of sedges. Further shallowing was accompanied by the establishment of *Sphagnum*, an establishment that implies a decrease in fertility ("oligotrophication").

Over the uphill half (approximately) of the peatland unit (Perkins 1985), the continuing accumulation of peat (largely the remains of *Sphagnum* and some wood) was sufficient to raise the surface into a convex form (and ombrotrophic condition). The raising of the surface promoted the spread of the peatland onto adjacent upland (sites 1–3: Figs. 3 & 4). This process of lateral spread of peatland to where neither lake nor peatland existed before is evidenced by the absence of lake sediments and the presence of woody peats with *Sphagnum* or fibrous peats directly overlying mineral soil. Lake sediment is also absent at site 2C along transect 2, the uphill end of transect 11, both ends of transect R, and the south ends of transects L-A, S, and Q. Upland islands in the original lake and early peatland were also overspread by the thickening peat (Figs. 3 & 4).

In summary, the south eccentric unit at Smith Brook Deadwater was formed by two different processes: primarily, by filling of a lake (a process called terrestrialization), and secondarily, by wetland formation on land (processes called paludification and "primary mire formation," as described later in report) along the shores of the original water body.

Eccentric Bogs Outside Maine

Descriptions of eccentric bogs

Eccentric bogs have been reported in northern Europe by several authors. Moore and Bellamy (1974) described "excentric raised bogs" or "excentric raised mires" as having initially formed on valley slopes that contained basins for accumulation of primary peat. The authors proposed that those accumulations served as nuclei for the formation of secondary and tertiary peat. With further growth, the tertiary peat masses coalesced and eventually formed a cupola "which appears to hang on the side of the valley" (Moore and Bellamy 1974:22). Moore (1977) described Claish Moss, Scotland, an

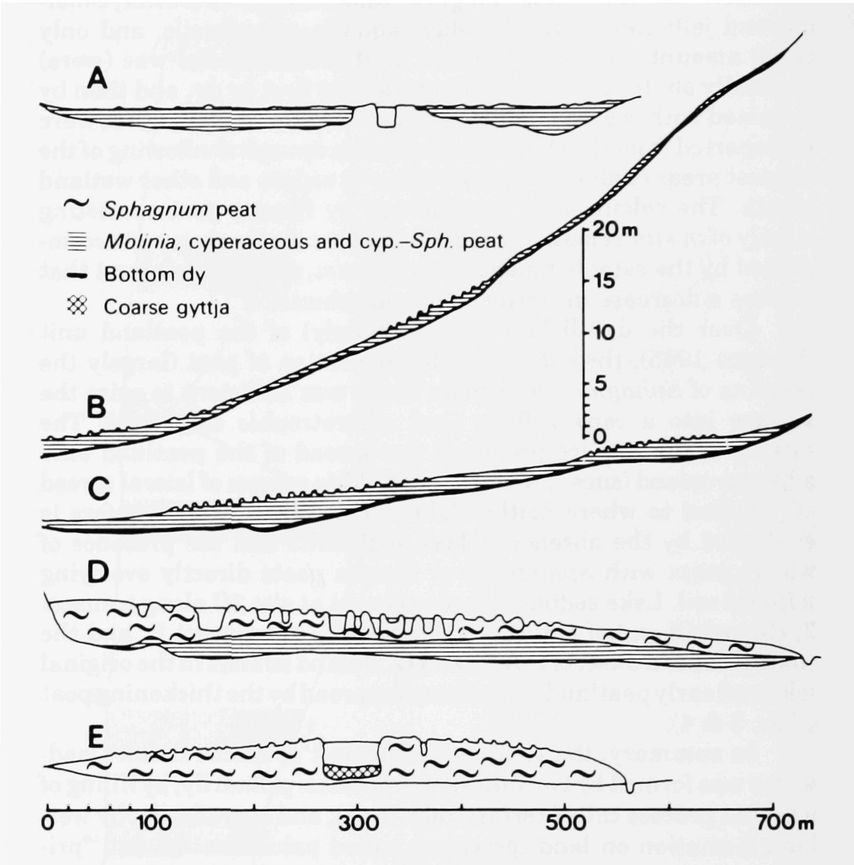


Figure 5. Profiles of central Swedish peatland (mire) types. A = horizontal fen; B = strongly sloping fen locally with flarks (ribbed/string fen); C = slightly sloping fen with flarks (ribbed/string fen); D = eccentric bog; E = concentric domed bog. 10X vertical exaggeration. Reprinted, with permission, from Sjörs (1983:76).

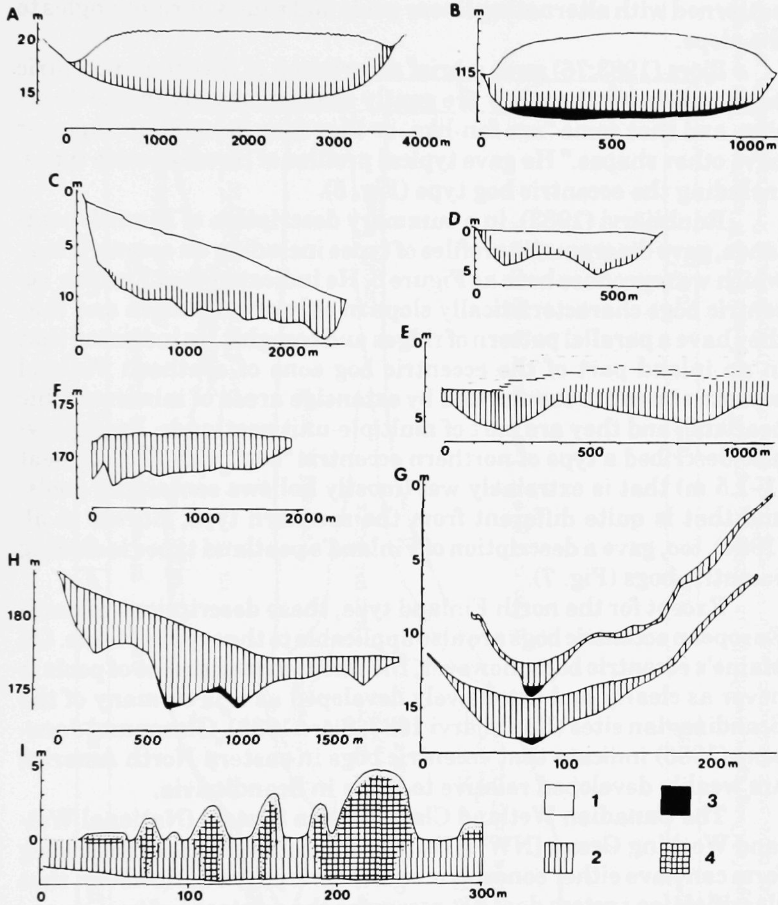


Figure 6. Profiles of Finnish peatland (mire) types. A = plateau bog; B = concentric bog; C = eccentric bog; D = *Sphagnum fuscum* bog; E = northern eccentric bog; F = southern aapa mire; G = sloping aapa mire; H = aapa mire; I = palsa mire. 1 = ombrotrophic peat; 2 = minerotrophic peat; 3 = limnic sediments; 4 = permafrost. (aapa mire = ribbed or string fen). Reprinted, with permission, from Ruuhijärvi (1983:52).

eccentric bog located between a lake and high ground, which is patterned with alternating linear pools and ridges at right angles to the slope.

Sjörs (1983:76) gave a brief description of Sweden's eccentric bogs, indicating that they are gently sloping, usually in one direction, and that some "are fan-like, or they may be saddle-shaped or have other shapes." He gave typical profiles of Swedish mire types, including the eccentric bog type (Fig. 5).

Ruuhijärvi (1983), in a summary description of Finnish peatlands, gave diagramatic profiles of types including an eccentric bog, which we reproduce here as Figure 6. He indicated that Finnish eccentric bogs characteristically slope in only one direction and that they have a parallel pattern of ridges and troughs. He indicated that in an inland part of the eccentric bog zone of southern Finland eccentric bogs are surrounded by extensive areas of minerotrophic peatland, and they are part of multiple-unit peatlands. Ruuhijärvi also described a type of northern eccentric "bog" with thinner peat (1–1.5 m) that is extremely wet (mostly hollows containing pools) and that is quite different from the southern type. Eurola et al. (1984), too, gave a description of Finland's peatland types including eccentric bogs (Fig. 7).

Except for the north Finland type, these descriptions of north European eccentric bogs are also applicable to the type in Maine. On Maine's eccentric bogs, however, the linear arrangement of pools is never as clearly and extensively developed as it is on many of the Scandinavian sites (Ruuhijärvi 1983; Sjörs 1983). Glaser and Janssens (1986) indicate that eccentric bogs in eastern North America are weakly developed relative to those in Scandinavia.

The Canadian Wetland Classification System (National Wetland Working Group [NWWG] 1988) indicates that the domed bog form can have either concentric or eccentric pattern. However, that classification system does not recognize the existence of true eccentric bogs in Canada, as defined by us and by the north European authors. The Canadian System does include a category called "Slope Bog," common in temperate to subarctic oceanic climates as in eastern Nova Scotia and Newfoundland, but this type does not have a surface that is appreciably raised above the surrounding terrain, and peat depths are generally only 1–2 m (NWWG 1988). It may be similar to Ruuhijärvi's (1983) northern eccentric bog.

Known global distribution of eccentric bogs

In mapping the "zonation of the mires of Europe," Moore and Bellamy (1974: Fig. 2.2) indicated a zone of "excentric raised bogs" and "Kermi Hochmoore" (patterned bogs including eccentric ones:

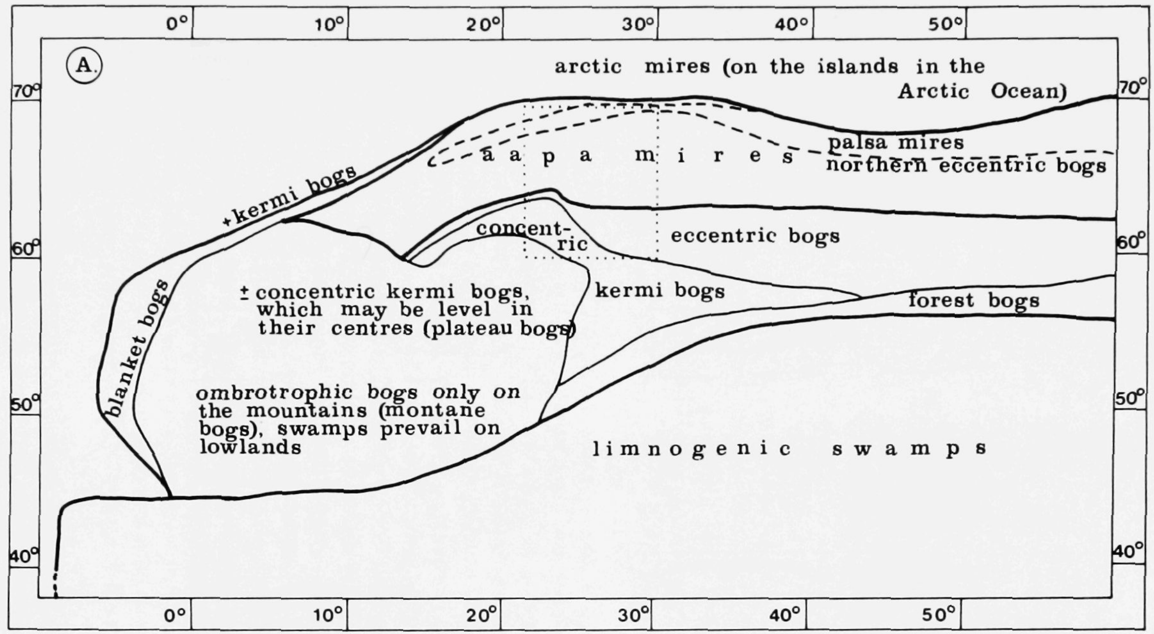


Figure 7a. Main peatland (mire) types of Europe. (a) Geographic distribution in relation to degrees N latitude and E and W longitude. The geographic position of eccentric bogs, intermediate between concentric and forest bogs to the south, and aapa mires (ribbed/string fens) to the north, is similar to the position of eccentric bogs in Maine. Finland is marked by rectangle. The small number of eccentric bogs in Scotland (see text) is not represented. Alpine peatlands are not indicated. (b) Schematic plans and cross sections (next page). Reprinted, with permission, from Eurola et al. (1984:27).

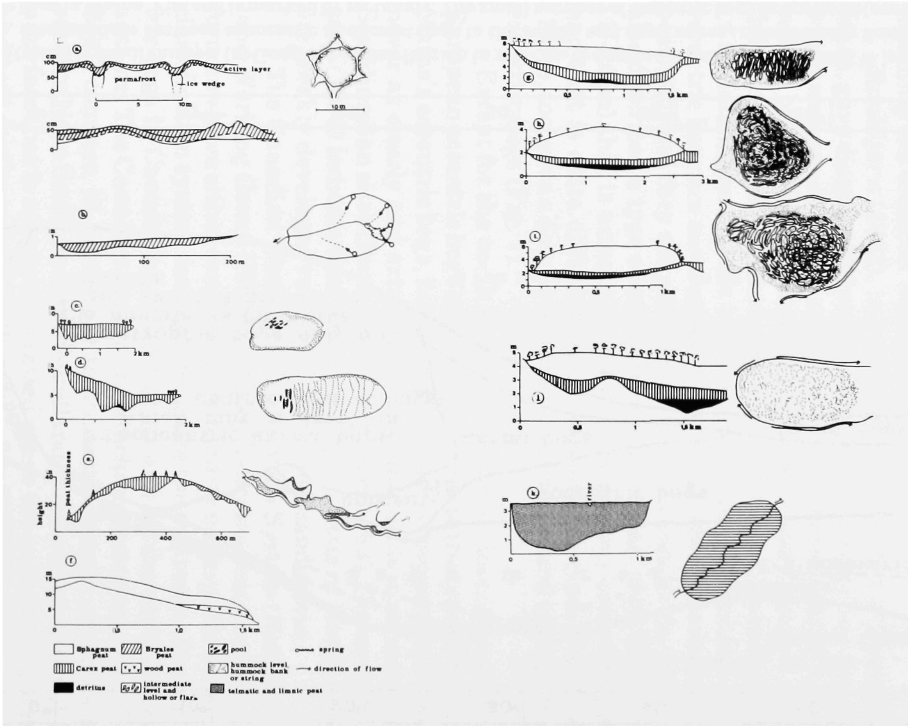


Figure 7b. Main peatland (mire) types of Europe. Schematic plans and cross sections. a = arctic mire with polygons (above) or with just hummocks (below); b = alpine mire; c = aapa fen; d = aapa fen; e = sloping fen; f = blanket bog; g = eccentric bog; h = concentric bog; i = concentric bog with central plateau; j = forest bog; k = limnogenic swamp. Reprinted, with permission, from Eurola et al. (1984:28).

Ruuhijärvi [1960]) in inland south-central and southeastern Finland, and extending into a small area of the Soviet Union. According to Ruuhijärvi (1983), the eccentric type is best developed in eastern Finland (province of North Karelia) where it was described by Tolonen (1967).

Apart from a single example from Scotland (Claish Moss), eccentric bogs were not mentioned by Moore and Bellamy (1974) as occurring outside their mapped Finland-U.S.S.R. area. Taylor (1983), in a summary description of peatlands in Great Britain and Ireland, did not mention the existence of eccentric bogs there. However, several eccentric bogs in Scotland have been described by other authors (Boatman and Tomlinson 1973; Boatman 1983; Lindsay et al. 1983; Ratcliffe 1977; Ratcliff and Walker 1958).

Sjörs (1983) indicated that "eccentrically developed bogs" (by which, he means what we are calling eccentric bogs) are quite common in west and central Sweden. Gore (1983) reproduced Moore and Bellamy's Figure 2.2 map and in the caption quoted a personal communication from Sjörs to the effect that the area of Sweden mapped by Moore and Bellamy as a zone of concentric bogs is really dominated by eccentric bogs. The geographic distribution of eccentric bogs in Europe was summarized by Eurola et al. (1984) (Fig. 7a).

Despite the omission of eccentric bogs from the Canadian Wetland Classification System (NWWG 1988), they may exist in the Atlantic Boreal Wetland Region of Canada, an area covering most of New Brunswick, Nova Scotia, eastern Quebéc including Gaspé, southern Labrador (mainland), and parts of Newfoundland. In peat resource surveys of Nova Scotia, peatlands fitting the description of eccentric bogs have been reported for Cape Breton Island (A.R. Anderson pers. comm.). In New Brunswick, the existence of eccentric bogs has neither been documented nor precluded (David Keys pers. comm.). It is not clear whether Wells and Pollett (1983) include true eccentric bogs in their type "eccentric domed bog" in Newfoundland. A re-evaluation of peatland form and hydrology in the Atlantic Boreal Wetland Region of Canada may indicate that eccentric bogs are more widespread in North America than is known at present.

APPROACHES AND PROCEDURES

Distribution and Abundance of Eccentric Bogs in Maine

To determine the distribution and abundance of eccentric bogs, we first had to decide where to look. Prior research provided guidance. On the basis of an air photo survey of 357 of the larger (>~80 acres; >~32 ha) peatlands throughout Maine, Davis et al. (1983) had located seven eccentric bogs in northeastern and one in north-central Maine. Since 1983, other peatland investigators have either (1) located no additional sites (Widoff and Ruffing [1984]: working in central, eastern, and extreme northeastern Maine), or (2) located two additional sites in the same general area as Davis et al.'s (1983) seven sites (Sorenson 1986[4]: working in northern Maine). These results indicated that the most promising area for search for additional eccentric bogs was northeastern Maine, namely north of 45°N, east of 69°W, and south of 47°N. An adjacent tract just to the southeast, in northern Washington County, and sparsely sampled by Davis et al. (1983: Fig. 2) also warranted further survey.

Accordingly, an area of eastern and northeastern Maine including the nine confirmed sites, and northern Washington County, and covering 27 USGS 15' quadrangles (Fig. 8) was surveyed in early 1987. The survey of the 27 quads consisted of careful examination of 1:16,000 stereo black-and-white air photos at the Maine Geological Survey photo library, except for quad areas where photos were missing from the collection. Missing were the areas of three complete quads, Tug Mtn, Stacyville, and Houlton; almost all of Wesley; most of the northern half of Amity; the eastern quarter of Smyrna Mills; the northeastern sixth of Mattawamkeag Lake; and smaller blocks of the Sherman, Mattawamkeag, and Lincoln quads. When a wetland area on one of these quads looked promising, the reduced photos of the flight line index were examined under magnification.

The search was not limited to the 27 quadrangles. Air photo searches for eccentric bogs again were made in 1988 during fen research throughout the state. Since 1982, a total of 572 Maine peatlands have been studied on air photos; 172 of these have been

---

[4]Sorenson (1986) listed seven "eccentric raised bogs," of which (1) one previously had been described by Davis et al. (1983): Coffin Bog; (2) three were renamed sites ("——") that previously had been described under different names by Davis et al. (1983): "Moosehead Bog" = Peatland 2 km South of Greenville Junction, "Macwahoc Bog" = Peatlands along Macwahoc Stream, and "Smith Brook Bog" = Peatlands at Smith Brook Deadwater and Little Smith Pond; and (3) two were new sites, as confirmed in this study: "Crossintic Stream Bog" [sic] = Peatland at Crossuntic Stream and County Line (this study), and "Wadleigh Brook Bog" = Wadleigh Bog (this study). The seventh, Meddybemps Heath was studied by Davis et al. (1983:168) and was not considered to be or to include an eccentric bog.

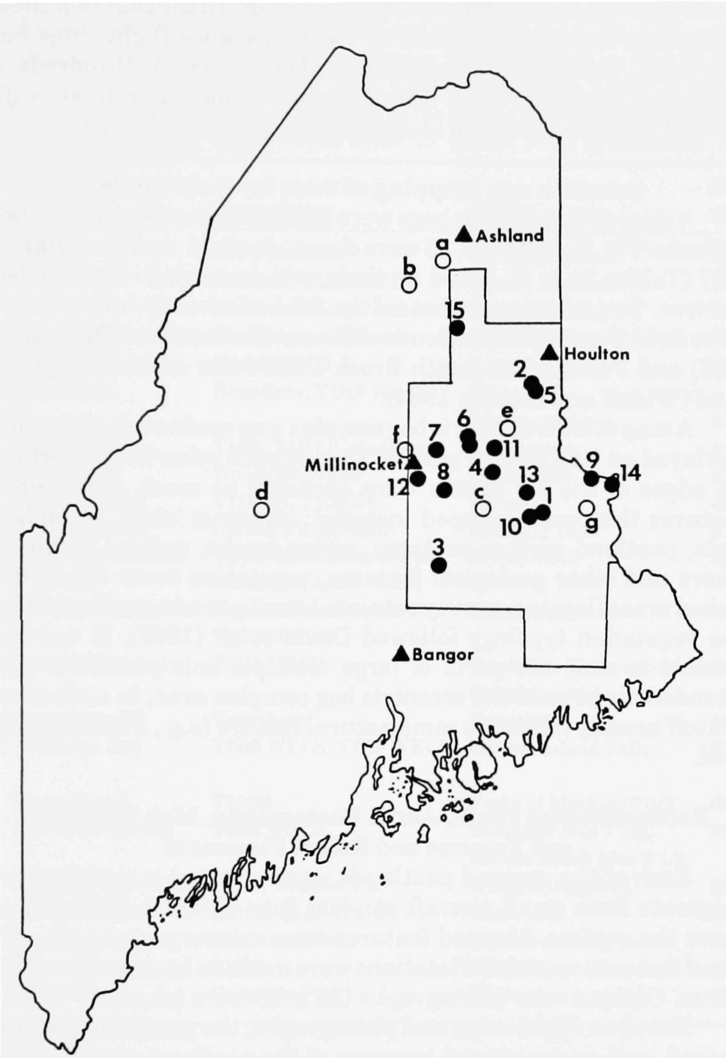


Figure 8. Map of Maine showing locations of eccentric bogs studied. Numbers indicate bogs studied on air photos, from aircraft, and by visit on foot in 1987. Sites d and f were studied in these three ways in earlier projects, by Davis et al. (1983) and Widoff and Ruffing (1984), respectively. Sites c, e, and g were studied on air photos and from aircraft; sites a and b only on air photos. The bogs are listed by name and their locations specified in Table 3 a & b. Air photo search for eccentric bogs was made of outlined area which encompasses 27 USGS 15' quandrangles.

observed in detail from aircraft at low altitude. In the course of these projects an extensive network of reconnaissance flight lines has been built, covering the entire state (Davis 1989a). Hundreds of additional peatlands have been observed along these lines, with especial attention given to identification of peatland types.

Selection and Mapping of Sites for Field Study

A total of 22 eccentric bogs were located by the aforementioned methods (Fig. 8). Of these, 15 were chosen for field study in summer 1987 (Tables 3a & b), based on their well-developed eccentric bog features. Two additional sites (of the 22) had already been studied in the field: Peatland 2 km South of Greenville Junction (Davis et al. 1983) and Peatland at Smith Brook Deadwater and Little Smith Pond (Widoff and Ruffing 1984).

A map of each eccentric bog complex was made on drafting film overlayed on 1:16,000 air photos. To minimize spherical distortion, the edges of the air photos were excluded as much as possible. Features that were mapped included: streams, lakes, secondary pools, peatland surface patterns, water tracks, upland "islands," eskers and other geological features, vegetation cover types, disturbed areas (logging, survey cuts, etc.), trails, roads, and buildings. The vegetation typology followed Davis et al. (1983). It was not possible to map the parts of large multiple-unit peatlands that extended far beyond the eccentric bog complex area; in such cases a cutoff usually following some natural feature (e.g., a stream) was used.

Reconnaissance Flight, Aerial Photography, Map Revision, and Traverse and Relevé Placement

Each of the mapped peatlands was subjected to aerial reconnaissance from small aircraft at ~500 ft to ~1500 ft (150–450 m) above the surface. Mapped features were reinterpreted and additional features recorded. Notations were made on best routes of field access. Oblique color photographs (35 mm) were taken.

Based on flight notes and photographs, the peatland map was revised, and an on-ground traverse of the peatland was planned. The traverse line was drawn on the map. The goal of the traverse was to cover as many vegetation types and other peatland features as possible in a one day visit (the bog at Cold Stream, by far the largest in this study, was visited for four days). Compass bearings of the traverse lines were determined. Approximate locations for vegetational relevés (see below) were recorded. The objective was to place relevés in as many of the major vegetation types as possible in the limited time available.

Table 3a. Eccentric bog site location information. The peatland numbers and letters correspond to the numbers and letters on the peatland location map (Fig. 8). The 15 numbered peatlands were sampled on foot in this study. If a peatland is named on a USGS quad, that name is given; otherwise, a short location-descriptive name is used (full name equivalents appear in Table 3b). USGS quads cover 15' unless 7 1/2' is specified.

No./letter & short name	Townships	USGS quads	Alt. (ft)
1. Big Bog	T7R2 Kossuth	Scraggly Lake	430
2. Coffin Bog	Linneus, TAR2 WELS	Amity, Houlton	575
3. Cold Stream	Passadumkeag, Lowell	Passadumkeag	145
4. Crossuntic Stream	Macwahoc, Kingman	Wytopitlock	370
5. Elevenmile Lake	TAR2 WELS	Amity	590
6. Flinn Pond	Benedicta, T1R5 WELS	Sherman, Mattawamkeag	530
7. Hatham Bog	T1R6, T1R7 (Grindstone)	Millinocket	375
8. Inman Bog	Woodville, T2R9	Millinocket	335
9. Lambert Lake	T11R3N, T10R3N	Forest	430
10. Lindsey Brook	Carroll Plt, Kossuth	Scraggly Lake	510
11. Macwahoc Stream	Upper Molunkus, North Yarmouth Acad. Grant	Wytopitlock	535
12. Nollesemic Stream	Hopkins Acad. Grant (E), TAR7 WELS	Millinocket	375
13. Stetson Mountain	T8R3 NBPP	Danforth, Wytopitlock, Scraggly Lake	615
14. Vanceboro RR	Vanceboro	Vanceboro	400
15. Wadleigh Bog	T7R6 WELS, T7R5 WELS	Oxbow, Island Falls	970
a. Carry Brook	T10R6	Forks of Machias 7 1/2	680
b. Chandler Stream	T9R8 WELS	Chandler Mtn 7 1/2, Middle Brook Mtn 7 1/2	850
c. Contrary Brook Bog	Winn, Webster Plt	Winn, Springfield	330
d. Greenville Jctn	Little Squaw (T3R5)	Greenville	1055
e. Orcutt Brook	Glenwood Plt	Mattawamkeag Lake	550
f. Smith Brook Dwtr	T1R8	Millinocket, Norcross	500
g. Todd Farm	Codyville Plt	Waite	250

Table 3b. Eccentric bog full names and sampling information. Short name equivalents used in Table 3a and elsewhere in this report are given. Field dates are 1987, except where indicated. Hours on peatland do not include periods walking to/from edge of peatland from/to automobile. No. rels = number of relevés. No. water = number of interstitial water samples taken from relevé sites, followed, in parentheses, for some peatlands by letter entries for each sample from an observation point (= O), stream (= S), or secondary pool (= P).

Peatland numbers & full names	Short names	Field dates	Hrs on ptld	No. rels	No. water
1. Big Bog	Big Bog	30VII	7	5	5
2. Coffin Bog	Coffin Bog	14VIII	6.5	5	5
3. Peatlands around Little Cold Stream & confluence of Cold Stream & Passadumkeag River: North unit, South Unit, & Unit South of Passadumkeag River	Cold Stream	16–22VII	30.5	15	11(O,S)
4. Peatland at Crossuntic Stream and County Line	Crossuntic Stream	27VII	7	6	5(S)
5. Peatland at Elevenmile Lake	Elevenmile Lake	13VIII	6.5	5	5
6. Peatlands on North and South Shores of Flinn Pond	Flinn Pond	18VIII[a]	6.5	5	5
7. Hatham Bog	Hatham Bog	11VIII	5	5	5
8. Inman Bog	Inman Bog	7VIII	6.5	5	5
9. Peatland Northwest of Lambert Lake	Lambert Lake	10VII	6	5	5
10. Peatland around Confluence of Lindsey Brook and Baskagegan Stream	Lindsey Brook	28VII	7	5	5(P)
11. Peatlands at Macwahoc Stream (units west, southwest and south of Juniper Brook outlet, and around Reed Deadwater)	Macwahoc Stream	23VII	8	5	3(P,P,P,S)
12. Peatland at Nollesemic Stream and Mud Brook	Nollesemic Stream	10VIII	5.5[b]	4[b]	4
13. Peatland at West Base of Stetson Mountain	Stetson Mountain	30VI	8.5	5	5(O)

continued

Table 3b. Continued.

Peatland numbers & full names	Short names	Field dates	Hrs on ptld	No. rels	No. water
14. Peatland at Origin of Salmon Brook, just west of Vanceboro RR Yard	Vanceboro RR	9VII	7.5	5	5
15. Wadleigh Bog	Wadleigh Bog	5VIII	7.5	5	4
a. Peatland at Carry Brook	Carry Brook				
b. Peatland at Chandler Stream	Chandler Stream				
c. Contrary Brook Bog	Contrary Brook Bog				
d. Peatland 2 km South of Greenville Junction	Greenville Jctn	1VII82[c]	7	5	0
e. Peatland around Orcutt Brook Deadwaters	Orcutt Brook				
f. Peatlands at Smith Brook Deadwater and Little Smith Pond	Smith Brook Dwtr	19VII84[d]	8	4	0
g. Bog Centered 1 km North of Todd Farm	Todd Farm				

[a]North unit only.
[b]An additional relevé was compiled during an additional 1 1/2 hours at a nearby small kettle-hole fen north of Nollesemic Stream.
[c]Davis et al. (1983).
[d]Widoff and Ruffing (1984).

Field Studies

Traverse

The 15 bogs were visited between 30 June and 18 August 1987 (see Table 3b for individual dates). The field crew consisted of two to four persons. It was usually necessary to gain access to the peatland by off-trail travel, occasionally in part or entirely by canoe(s). Access had been planned so that, upon reaching the edge of the peatland, the map position would be known. At that point, the traverse line began and was followed using a Silva Ranger compass. Landmarks (e.g., a distinctively shaped pool) were used to confirm or correct the crew's position whenever necessary and possible.

Along the traverse, a profile of vegetational structure and physiognomy, micro- and macrotopography and other features (e.g., secondary pools) was sketched onto the field form (example given in Davis et al. 1983: Appendix III) with notes on vegetation types. An effort was made to record as many species of vascular plants, bryophytes, and lichens as possible in each vegetation type and to search for rare and unusual species. Algae and fungi and epiphytic species of any kind were not recorded. Strictly aquatic species were consistently recorded only if they occurred in secondary pools. These species were few in number. The more numerous species in streams and primary bodies of standing water were only incidentally tallied, and only if floating or emergent. Outstanding physical features (e.g., water tracts) were checked and photographed whenever possible.

Relevés

While original mapped positions of relevés were roughly followed, precise final placements were determined in the field so as to best represent each vegetation type (and to avoid anomalous conditions). This was crucial because time was insufficient at each peatland for more than a small number of relevés. In general, the relevé procedures of Davis et al. (1983) were followed. At each 5-x-5-m relevé:

> data were collected on the structure and composition of the vegetation, as well as on the abundance (recorded percent cover) of individual species. These data together constitute a relevé (a French term that refers to a vegetation sample). Our relevés were modified to include not only presence and abundance of species (Braun-Blanquet 1932; Mueller-Dombois and Ellenberg 1974) but also structural characteristics of the sampled area (following methods of Küchler [1967]). The result is a list of species and their percent cover for each separate layer in the vegetation at each site. An example of a completed data form used in the field for one relevé is given in Appendix IV (Davis et al. 1983:40-41).

The four layers (strata) for which data were recorded were: (1) moss (ground), 0-0.1 m; (2) low shrub-herb, 0.1-1.5 m; (3) high shrub, 1.5-5 m; and (4) tree, >5 m. Microrelief (maximum) in each relevé was estimated to the nearest 0.1 m. To ensure as complete as possible a list of flora for the vegetation type represented by a relevé, a careful search for species was made in the vicinity (~15 m circle) of the relevé. In addition, a color photograph (35 mm slide) was taken of each relevé. The photos are a part of the peatland database at the University of Maine. Relevé parameters and procedures are summarized in Table 4. An example of a completed relevé field form was given as Appendix IV by Davis et al. (1983). Four to six (usually 5) relevés were completed at each peatland, with the exception of the bog at Cold Stream where 15 relevés were completed, for a total of 85 relevés at the 15 peatlands (Table 3b). (Samples for chemical and peat stratigraphic analyses were also taken at relevés; see below.)

Table 4. Summary of relevé parameters and procedures and floral reconnaissance of peatland.

Types of plants sampled:	vascular, bryophytes, and lichens
Size of relevé:	5 x 5 m
Number of relevés:	4–15 per bog $\bar{x}$ = 5.8 per bog total = 85
Strata sampled separately:	1. moss (ground) (<0.1 m) 2. low shrub herb (0.1–1.5 m) 3. high shrub (1.5–5.0 m) 4. tree (>5 m)

Plant species tallied according to the following abundance/cover class estimates:

R = solitary small individual (<0.1% cover)
+ = few individuals, totaling 0.1%–0.5% cover
1 = numerous small individuals or few large individuals totaling 0.5%–5.0% cover
2 = 5%–25% cover
3 = 25%–50% cover
4 = 50%–75% cover
5 = >75% cover

Record made of plant species present in ~15 m radius circle around relevé

Plant species recorded along traverse

Observation points

At some of the peatlands, in addition to relevés, vegetational information was gathered at observation points. Although not as quantitative as the relevé, the information gathered at observation points was more detailed than that gathered along the rest of the traverse. In addition, peat stratigraphic information and/or samples were gathered at all but one of the observation points. Observation points were established when time was inadequate for establishing relevés, but where information was needed for understanding some important aspect of the vegetation or development of the peatland. Observation points are identified on the peatland plan maps later in this report.

Relevé and observation points together totaled 110. These (together) ranged from four at Nollesemic Stream to 29 at Cold Stream. Apart from Cold Stream, there was an average of 5.8 per peatland. With so few sampling points per peatland, it was not possible to sample all vegetation types. That fact and the limited number of hours that could be spent at each peatland (Table 3b) mean that these data only marginally characterize the vegetation of individual peatlands. Nevertheless, the entire data set provides an adequate representation of the major vegetation types of the eccentric bogs (in general) of Maine.

Occasional uncertainty in species identification occurred at the relevés and along the traverse, usually due to plant immaturity. Such specimens were collected for laboratory study. Species that could not be identified were listed by genus and "sp." or "spp." When these abbreviations were used with a genus that also had identified species at the same peatland, the abbreviations implied different species from the identified one(s), unless the term "unspecified" was added in parentheses. Unspecified species may or may not have been different from the identified ones. These conventions were carried over to the master floristic list (Appendix 1), and the logic was extended to the counting of species for determination of floristic diversity. For that purpose, "spp." lacking the term "unspecified" was counted as only two different (but unknown) species of the genus. In only a few cases was this conservative approach likely to cause an underestimate of diversity and then only to a very small degree. Unspecified species were not counted as different.

Taxonomic terminology follows Fernald (1979) for vascular plants and Crum and Anderson (1981) for mosses except for Sphagnaceae for which Crum (1984) is followed.

Water samples for chemical analysis

At each relevé, a 150-ml sample of peat interstitial water was taken from the acrotelm.[5] Water from the top 5–15 cm of the water table was collected by inserting into the peat a 60-cm-long by 3-cm-diameter cellulose carbonate collection probe with a series of 2-mm holes for flow into the bottom 20 cm of the probe. The water was drawn by hand vacuum pump via flexible plastic tubing from the *in situ* probe into a 500-ml polycarbonate filter flask and then poured from the flask to the collection bottle. The top of the water table usually was 10–30 cm below the surface, so the probe usually did not have to be inserted its full length to obtain the top 5–15 cm of water. In eight instances in dry periods, the top of the water table was below the lowest inlet holes of the fully inserted probe, and no water samples could be collected. A total of 77 peat interstitial water

---

[5]At each relevé a 250-cm^3 sample of peat for chemical analysis was cut from just below the the living green surface layer. Peat chemistry is reserved for a later report; only the interstitial water chemistry is included here.

samples from relevés was collected (Table 3b). In addition, two peat interstitial water samples were collected at observation points, four water samples from bog pools and three from streams (Table 3b). Two pool and two stream samples were lost.

Polyethylene collection bottles were pretreated by an overnight soak in 10% HCl followed by glass-distilled water rinses. Bottles with field samples were transported in a cooler with ice or stored in a refrigerator or both until return to the laboratory (usually the same or next day).

Sediment and peat stratigraphy

A 15-cm-long by 2-cm-diameter Davis peat sampler with 3-ft (0.91-m) rods was used for reconnaissance sampling of sediment and peat stratigraphy. At each relevé, samples were taken at 3-ft intervals below the surface, including mineral substrate for the deepest sample (when that substrate could be penetrated). The depth of the interface between organic deposit and mineral substrate was sometimes determined more precisely by taking samples at shorter than 3-ft intervals. In addition, the peat at 6–10 inches (0.15–0.25 m) below the surface was sampled by hand grab. Additional stratigraphic sampling was carried out at observation points at certain peatlands. The sediment and peat types were described in the field. For eleven of the peatlands, further examination of the samples was carried out at the laboratory. *In toto*, there were 113 sites of stratigraphic study (each with samples at multiple depths) at the 15 peatlands.

As was the case for sampling of vegetation, the peat stratigraphic sampling was sparse for individual peatlands. In addition, stratigraphic sampling was discontinuous. Time was inadequate for sampling entire sediment/peat columns. The results are marginal for understanding the origins and developmental history of individual peatlands. The approach was extensive, not intensive; the intent was to obtain a preliminary and general picture of origins and development of the eccentric bog type in Maine.

Laboratory Analyses

Chemical analyses

Upon return to the laboratory, and extending into the following day, the refrigerated water samples were filtered through Nucleopore 0.65 µm cellulose membrane filters. The filtrate was split in three for analyses of (1) pH and total alkalinity (=acid neutralizing capacity or ANC), (2) dissolved organic carbon (DOC), and (3) conductance and selected chemical elements. The DOC subsample was preserved by adding strong acid, and all subsamples were refrigerated until analysis.

The first two subsamples were analysed by the Watershed Manipulation Project laboratory (Univ. Maine) using, respectively, (1) a Radiometer Acid Rain Analysis System (ARAS) automated Gran-plot titrator, and (2) an OI-700 Total Carbon Analyser. The pH/ANC sample was aerated with standard air just prior to pH determination and titration with 0.020N SO_4. Precision for pH was 0.01 unit. DOC standards for machine calibration were prepared by dilution of 2000 ppm stock solution of potassium hydrogen phthalate. Detection limit for DOC was 0.01 ppm.

The third subsample was analyzed by the Maine Agricultural Experiment Station Analytical Laboratory for Ca, Mg, P, Al, Fe, Mn, Zn, and Si by plasma spectrometry (Jarrel-Ash ICP); K and Na by flame spectrometry (Instrumentations Mod. Video 12); NH_4 by Wescom Ammonia Analyzer; and anions by ion chromatography (DIONEX Mod. 2000 I/SP with conductance detector); and conductance. The detection limit for Cl was 0.001 ppm; for NO_3-N 0.002 ppm; for Mg, Mn, Zn, and SO_4-S 0.005 ppm; Ca, P, and Si 0.01 ppm; Fe 0.02 ppm; Al and Na 0.05 ppm; NH_4-N and K 0.1 ppm. There was a total of 18 chemical variables. Suitable blanks and standards were used in all cases.

Database and statistical analyses

Vegetational and chemical data have been stored on PC hard disk (with floppy disk backup) by means of *Dbase III Plus* programs. Multivariate statistical analyses including ordinations were carried out to distinguish the patterns of vegetational variance and to relate this variance to chemical conditions. For this work, the University of Maine IBM 370 mainframe computer was used.

Chemical data were log transformed prior to analysis. Principal components analysis (PCA) of the transformed data was carried out by BioMed Program BMDP4M. There were 17 input variables (ANC was omitted) and 82 samples (77 from relevés; two from observation points, two from pools, and one from a stream).

The vegetation data for analysis consisted of the combined data from all strata. Detrended correspondence analysis (DECORANA) and two-way indicator species analysis (TWINSPAN) of the vegetational data were performed by Cornell Ecological Program Series CEP 40.

TWINSPAN is a form of "dichotomized ordination analysis" (Hill 1979). The input data consisted of the 94 species that occurred in two or more relevés, regardless of abundance. While all 85 relevés were used for TWINSPAN, only 84 relevés were used for DECORANA. The 85th relevé (CS6), from a streamside meadow, severely skewed the results and was omitted.

Canonical correspondence analysis (CCA) was carried out on the combined chemical and vegetational data sets by the CANOCO program of ter Braak (1987). There were 77 active samples (relevés with interstitial water chemistry) and 8 passive samples lacking chemistry. The chemistry inputs were the same as for PCA, except that NO_3-N and NH_4-N were omitted because each had large majorities of "zero" (below detection limit) readings.

As each peatland and relevé site was sampled for interstitial water chemistry on only a single date, small differences between peatlands and between relevé sites on the same peatland are unlikely to be meaningful given the probably considerable temporal variation in chemistry due to weather, season, etc. Nevertheless, major and consistent chemical patterns and vegetation/chemical relationships, formerly inferred for Maine solely on the basis of literature from other regions (Davis et al. 1983), may be revealed or confirmed by these techniques within statistical ranges of confidence.

Areal coverage of peatland and vegetation cover types

Mapped peatland and vegetation areas (m^2) were determined on a Hitachi HDG 3640 digitizer with AUTOCAD software. These analyses covered the entire plan-mapped area of each peatland. All determinations were carried out by the same technician. To test the methodologic variance, a peatland (Coffin Bog) with typically complicated vegetation patterns was chosen for replicate (n = 7) determinations. Each determination was carried out on a different day. For each of the 11 separately tallied vegetation types and total mapped area, the extreme difference was calculated ([max - min]/max). These twelve differences ranged from 1.0% to 14.8%, and averaged 7.3%. The smaller the vegetation area, the greater the percentage maximum difference. The maximum difference among determinations of area of the entire mapped peatland was only 1.0%.

Sediment and peat analyses

Peat stratigraphic samples were analyzed and described according to the Troels-Smith system and certain later modifications of that system (Aaby and Berglund 1986), except that simplified graphic symbols have been used for this report.

Evaluation of peatlands for their exemplary and unique features, and recommendation for Maine Critical Area status

Each peatland was evaluated using the method of Davis (1989b) to determine which of the peatlands should be recommended to the Maine Critical Areas Board for Critical Area designation. This evaluation method is based on three primary criteria: rarity, exemplariness, and diversity. These criteria are applied to four peatland characteristics: peatland types, other geological characteristics, vegetation types, and plant species. Peatland size (area) and pristine character are also considered. The percentage emphases on these criteria and characteristics are given in Table 5. For details of evaluation procedures refer to Davis (1989b).

Table 5. Percentage emphases on six characteristics and three primary criteria in peatland evaluation (from Davis 1989b).

	Primary criteria			
	Rarity	Exemplariness	Diversity	Totals
1. Peatland types	18	18	8	44
2. Other geological characteristics	1	2	2	5
3. Vegetation types	4	4	6	14
4. Plant species	16		12	28
5. Peatland size (area)				5
6. Pristine character				4
Totals	39	24	28	100

Summary of Approaches and Procedures

The approaches and procedures used in this study are summarized in Table 6.

Table 6. Summary of approaches and procedures used in this study of 15 eccentric bog complexes.

I. Aerial photo and flight reconnaissance of Maine to determine geographic distribution of eccentric bogs

II. Mapping of vegetation of each peatland from black-and-white stereo aerial photos, confirmed by:
- low-altitude flights including oblique aerial color photography
- ground truth (traverses)

III. On-foot traverse of each peatland:
- flora - presence
- vegetation types and other features

IV. Relevés at sites characteristic of vegetation/geomorphic zones of each peatland, and some additional observation points:
- vegetation/flora of relevé and flora of vicinity of relevé and at observation points
- peat interstitial water sample at relevé and samples from pools and streams for chemical analyses
- whole peat sample at relevé for chemical analyses[a]
- stratigraphic peat samples at relevé and observation points to determine peatland origins and development
- color photographic record of relevé and vicinity and at observation points

V. Laboratory and office analyses:
- determination by digitizer of areas of vegetation cover types on map of each peatland
- Troels-Smith analyses of peat stratigraphic samples
- analyses of peat interstitial water for 18 chemical variables (analyses also of whole peat[a])
- multivariate statistical analyses of vegetation and environmental chemistry data to determine patterns of variance and covariance
- evaluation of each peatland for its unique and exemplary character, and recommendations for Maine Critical Area status

[a]Results reserved for a later report

RESULTS AND DISCUSSION

Distribution and Abundance of Eccentric Bogs in Maine

The aerial photo survey and more general surveys confirmed earlier indications (Davis et al. 1983) of the geographic distribution of eccentric bogs. In Maine the peatland type occurs in the east, from 69°W (near Millinocket) to the New Brunswick border, between 45°N and 46°40'N. A single more western occurrence is the bog with weakly developed eccentric units two kilometers south of Greenville Junction, at 69°30'30"W. Other occurrences outside the main area may exist, but they are probably few. By far the greatest abundance of the type is centered in a relatively narrow band from Millinocket to New Brunswick, from 45°25'N (near Springfield) to 46°N (near Houlton) (Fig. 8). The distribution of eccentric bogs overlaps the northeastern part of the distribution in Maine of domed concentrically patterned bogs (Table 2; Fig. 9) (Davis 1989a).

Air photo study confirmed the existence of 22 eccentric bogs (Fig. 8). All but two of these (Carry Brook [site a] and Chandler Stream [site b]) in Tables 3a & 3b were also observed from aircraft. Five sites in addition to the 22, and within the 27 quad area, were thought to possibly be eccentric bogs, but were observed only on air photos and only briefly. More detailed study of them is required for confirmation of their eccentric bog character.[6] Where full-sized air photos were unavailable, reduced photos had to be used, as described in the methods. Altogether, this compromised method was used at 19% of the 27 quadrangle survey area (Fig. 8). Partial air photo surveys and aerial reconnaissance of quads in the area peripheral to the northern end of the 27 quadrangle area, carried out in 1988 as part of a survey of Maine fens (Davis and Anderson in prep. a), turned up two eccentric bogs (a and b in Fig. 8 and Table 3) with poorly developed eccentric features. In total, 22 eccentric bogs were confirmed and five[6] were unconfirmed. Davis (1989a) estimated that there are about 35 eccentric bogs in Maine. This estimate assumes that some of the uncertain sites[6] are *bona fide* eccentric bogs, that there may be a smaller number of unrecorded eccentric bogs peripheral to the main surveyed area, and that very few, if any, eccentric bogs were overlooked in the 27 quadrangle area due to missing full-sized air photos or error. The estimate of 35 eccentric

---

[6]None of these five sites has exemplary eccentric bog form. The sites are: (1) Hackmatack Bog and (2) peatland west of Dead Brook, both in Brookton Twsp, Danforth 15' quad; (3) Martin Bog, Molunkus and Mattawamkeag Twsps, Mattawamkeag 15' quad; (4) peatland ca. 1 mile west of south basin of Nicatous Lake, T40MD, Nicatous Lake 15' quad; and (5) peatland 1 mile northwest of Hound Brook Lake, T1R2, Waite 15' quad.

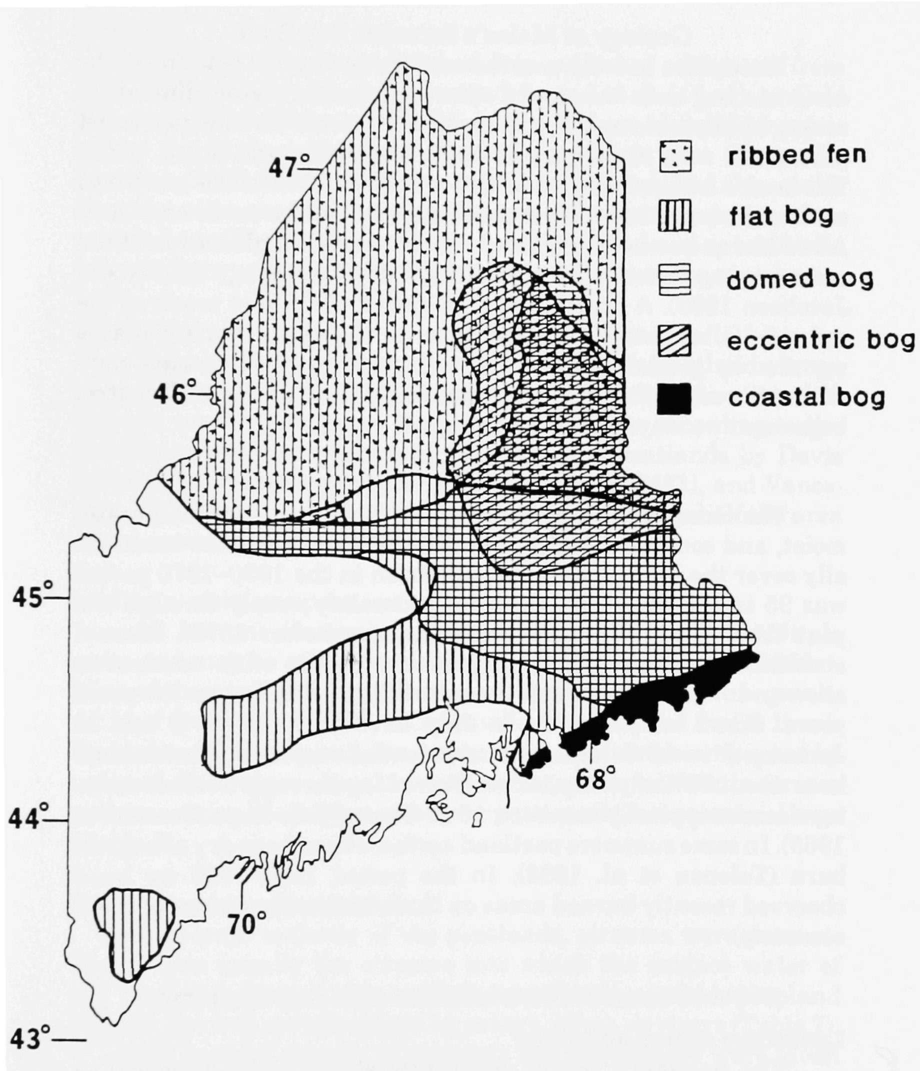


Figure 9. Map of Maine showing distribution of bogs and fens. Unpatterned forested and open fens occur throughout the state. From Davis (1989a).

bogs in Maine makes the type rare compared with other peatland types in the state. Several of these other types are represented by hundreds to over a thousand sites (Table 2; Davis, 1989a).

Geology of Maine's Eccentric Bog Zone

Most of the bedrock and the surficial geological deposits of the eccentric bog zone consist of siliceous/granitic metasedimentary rocks. Mildly calcareous metasediments occur in the northeast part of the zone (Osberg et al. 1986; Thompson and Borns 1986). The land is hilly, mostly 40–200 m above sea level in the south and east, and mostly 200–500 m above sea level in the north and west. All of Maine has been glaciated. The most recent glaciation of the eccentric bog zone ended 12,000–13,000 ^{14}C years ago (Davis and Jacobson 1985). A coarse and thin glacial till covers much of the upland. Valley bottoms and gentle lower slopes are in many places mantled by glaciolacustrine clay-silts, and by glaciomarine clay-silts at lowest altitudes in the southwest part of the zone. Eccentric bogs occur on clay-silts of both origins.

Climate of Maine's Eccentric Bog Zone

The climate of Maine's eccentric bog zone is cool-temperate, moist, and continental except that maritime air masses occasionally cover the area. Annual precipitation in the 1930–1970 period was 95 to 108 cm, distributed approximately evenly through the year (U.S. Dept. Commerce 1968; Lautzenheiser 1972). Annual snowfall ranged from 200 to 250 cm, usually with continuous snowcover from December through March and longer in some years. Mean temperatures in July have been 18°–20°C and in January -8° to -12°C. Mean annual potential evapotranspiration has been about 50% of precipitation. From May through October moisture excess typically has been 10 to 14 cm (U.S. Dept. Commerce 1968). In some summers peatland surfaces have been dry enough to burn (Tolonen et al. 1988). In the period 1980–1988 we have observed recently burned areas on three Maine bogs (none of them eccentric).

Physical Features of Maine's Eccentric Bog Complexes

Landscape setting and slope

The peatlands occupy the gentle slopes rising from valley bottoms. Their fen areas extend all the way to the valley bottoms where they usually border a stream or lake. Their bog areas are offset to various degrees upslope. The degrees of slope of the peatland surfaces and basal mineral substrates were not measured in this study, but as mentioned earlier, Perkins (1985) measured an average surface slope of 0.39% along the long axis of the southern eccentric unit at Smith Brook Deadwater. The slope of fen areas associated with eccentric bogs is even more gentle than that.

Altitudes

Altitudes above sea level of bog surfaces, estimated from USGS 15' topographic maps ranged from 145 ft (44 m) at Cold Stream to 970 ft (296 m) at Wadleigh. The highest altitude eccentric bog so far studied (Davis et al. 1983) in Maine is at Greenville Junction (1055 ft; 322 m) (Table 3a). The Wadleigh and Greenville Junction sites are peripheral to the main distributional area of eccentric bogs (Fig. 8); their relatively high altitudes may somehow (climate?) account for their existence peripheral to the main area.

Size (area)

The plan-mapped areas (later in text) of the peatlands range from 366 to 4130 acres (148 to 1672 ha) (Table 7), indicating that Maine's eccentric bogs are medium to very large according to the definitions of these relative terms for Maine peatlands by Davis (1989b). In certain cases (e.g., Big Bog [Figs. 20 & 21], and Vanceboro RR [Figs. 46 & 47]), the mapped area is less than half the area of the entire multiple-unit peatland.

Multiple units per peatland

All but one (Inman) of the peatlands consisted of multiple units and may be called "multiple-unit peatlands"[3] (Davis 1989a). Nine of the peatlands contained more than one eccentric bog unit. At 14 of the peatlands (16, if Greenville Junction and Smith Brook Deadwater are included) the eccentric units were accompanied by units of other types—most commonly unpatterned fens in stream valleys or open basins, but also by unpatterned (non-eccentric) bogs (Table 7).

Other physical characteristics

At a large majority of the peatlands, streams were present. These were usually the streams into which the surface water of the peatland drained. Many of the peatlands contained upland islands. Several were bordered by eskers, lakes, or rivers (Table 7).

The general aspects of eccentric bog morphology were given earlier. There is considerable variation around these general aspects, as can be seen from the detailed descriptions of peatland surface features and gross hydrology, and on the plan maps given later in the text. Exemplary surface features can be seen on the maps of Coffin Bog (Fig. 21) and the southeastern unit at Macwahoc Stream (Fig. 41).

Table 7. Important features and evaluation scores for peatlands sampled on foot. Entries are for only the plan-mapped areas, except where indicated. With one exception, these are multiple-unit peatlands consisting of more than one peatland type. See Table 2 for meaning of peatland type numbers. Exemplariness, on scale of 1 (best) to 5 (worst), is for the best (or only) eccentric unit at the peatland, except where otherwise indicated, and is judged on a national (U.S.A.) level. Other feature numbers mean: 1 = river, 2 = stream, 3 = lake, 4 = mountain rising directly from peatland, 5 = deep trough in landscape occupied by peatland, 6 = esker, 7 = kame, 8 = kettle, 9 = moraine ridge, 11 = mineral (upland) island, 12 = parallel pattern on peatland, 13 = water track on peatland, 14 = soak on peatland. Multiple occurrences of peatland types and other features, except for upland islands, are given in parentheses. D_c = index of species richness (containing correction for time spent on peatland) (Davis 1989b). If evaluation score using D_c differs from the score using number of species (Spp.), the former is also given (in parentheses). See text (beginning on page 88) for additional information on each peatland.

Peatland No. & short name	Acres (ha)	Peat-land types	Exem-pla-riness	Other features	Spp. score	D_c	Eval.
1. Big Bog	776 (314)	2(2),3,7	1	2(2),11, 12,6	58	30	49.5[a]
2. Coffin Bog	556 (225)	2,3,7(2)	1	2,11,12(2)	69	37	49.1
3. Cold Stream	4130 (1672)	2(5),7(2)	1	1,2(3), 6(2?),11, 12(2),13	188	55	63.0
4. Crossuntic Stream	946 (383)	2(4),3(2), 7	3	2(2),11, 12	69	35	34.0 (32.0)
5. Elevenmile Lake	395 (160)	2,3,6(a?) (2),7(2)	4	2,3,11,12	86	44	41.3 (35.3)
6. Flinn Pond	494 (196)	2,3,7(2)	3	2,3,6,12	75	40	34.7
7. Hatham Bog	366 (148)	6b,7(2)	4[b]	2,4,11, 12,13,14	58	36	35.3[b] (37.3)
8. Inman Bog	469 (190)	7	5	6,7,11,12	54	29	18.0
9. Lambert Lake	516 (209)	3,7	2	2,5,11,12	69	39	40.6
10. Lindsey Brook	546 (221)	2(3),7	3	2(2),11, 12	68	35	31.9[a] (29.9)
11. Macwahoc Stream	1095[c] (444)	2(3),7(2)	1	2(3),6, 11,12	116	56	55.9[a] (58.9)
12. Nollesemic Stream	484[d] (196)	2(2),3(2), 4,7	4	2(2),6,8, 9,11,12	37	22	27.9

continued

Table 7. Continued

Peatland No. & short name	Acres (ha)	Peat-land types	Exem-pla-riness	Other features	Spp. score	D_c	Eval.
13. Stetson Mountain	610 (247)	6a,7(2)	3	2,4,11, 12	102	48	43.2
14. Vanceboro RR	489 (198)	3(4),7	4	2,12	77	38	24.1[a]
15. Wadleigh Bog	454 (184)	2(4),7	2	2(2),12	65	32	38.8 (36.8)
d. Greenville Junction[e]	427 (173)	2(2),7(2)	5	2(4),6, 11,12	46	24	25.5 (24.5)
f. Smith Brook Deadwater[f]	521 (211)	2(2),3, 7(2+)	3	2(2),3(2) 12	68	33	43.9 (41.9)

[a]The total scores for these multiple-unit peatlands would be higher if the evaluation included the units that are outside the areas mapped for this study.
[b]A Type 6b bog unit at Hatham is rated 1 for exemplariness. When that unit is used in the evaluation for exemplariness of peatland type, the total score is 51.3 (53.3).
[c]Area of unit studied on foot: 254 acres (103 ha).
[d]Mapped area south of Nollesemic Stream only, containing eccentric unit. If mapped area north of stream, lacking eccentric unit but containing type 4 unit is included, total area is 657 acres (266 ha).
[e]From Davis et al. (1983).
[f]From Widoff and Ruffing (1984).

Most surfaces of the peatlands were irregular, in that a good deal of microrelief was present. Apart from the presence of linear patterns of ridges and troughs, a more irregular, smaller scale pattern (0.5–5.0 m) of hummocks and hollows was present. The degree of development of hummocks and hollows differed considerably among vegetation types, as will be described at the end of the section *Summary of relevé data.*

Flora of Maine's Eccentric Bog Complexes

A complete list of the identified plants, including ground lichens, bryophytes, and vascular plants, in the 15 sampled eccentric bogs is given as Appendix 1. The taxa are listed in order of number of relevés in which they were found. Due to uncertainties in identification of some taxa (see page 30), it is not possible to give a precise count of the total number of species and varieties found. We can say, however, that there were at least 240 different species and varieties.

Some taxa occur in all or nearly all of Maine's acidic wetlands/peatlands. Twenty-three taxa occurred at all 15 of the eccentric bogs, and 42 taxa occurred at 12 or more of them (Appendix 1). Among these taxa, the most abundant (mean cover in relevés >5%) were leather leaf (*Chamaedaphne calyculata*), sheep laurel (*Kalmia angustifolia*), Labrador tea (*Ledum groenlandicum*), *Sphagnum capillifolium* var. *tenellum* (= *S. rubellum*), *Sphagnum recurvum* aggr., *Sphagnum fuscum*, *Sphagnum magellanicum*, *Carex trisperma*, rhodora (*Rhododendron canadense*), and black spruce (*Picea mariana*). Certain other taxa that occurred at all or nearly all of the peatlands contributed much less to the plant cover, for example small-leaved cranberry (*Vaccinium oxycoccos*) ($\bar{x}$ = 2.3% cover) which seemed to be present everywhere on the open parts of the peatlands. Bog rosemary (*Andromeda glaucophylla*), too, occurred on the open area of every peatland ($\bar{x}$ = 2.0% cover), but its populations were clumped so the species was absent from most of the area.

There were also numerous species that occurred on only one or two of the peatlands (Appendix 1), but no truly rare species was found.

Vegetation of Maine's Eccentric Bog Complexes

As emphasized earlier, eccentric bogs are peatland (mire) complexes and usually are part of multiple-unit peatlands. Several vegetation types occur on the eccentric units themselves, not to mention the surrounding fens and other bog unit types, as indicated later on the plan maps. The vegetation types, abbreviations, and symbols used in tables, figures, and maps are given in Table 8. Certain of the vegetation types that have been mapped from aerial photos are general types ("vegetation cover types"), in that they consist of more than one specific vegetation type. We were not able to distinguish all specific types (Table 8) on aerial photos.

Areas of mapped vegetation cover types

These areas are given for each peatland as percentages of total peatland area (Table 9). A large proportion of the area of each peatland consisted of fen (28%–86%). Most of the fen was wooded fen, which was the most common vegetation cover type overall, ranging from 20% to 78% of the mapped area per peatland and averaging 52%. This type was largely concentrated away from the center of the peatland (see plan maps). Specific types of wooded fen, namely, angiosperm, mixed, and gymnosperm wooded fen, were not consistently distinguished when the mapping was done in 1987. However, it is possible to assert on the basis of relevé results and other observations that angiosperm wooded fen is uncommon in this peatland type and that both mixed and gymnosperm wooded fen occur extensively. Field studies suggest, however, that many of the areas mapped as wooded fen have a discontinuous (open) tree canopy and a well-developed understory of tall shrubs and are probably best classified as open wooded fen/shrub thicket fen types of vegetation (Table 8). Open wooded fen was mapped for only 0.0% to 6.9% (average 1.8%) of the peatland areas (Table 9), but obviously covers much larger areas. Also mapped for peripheral areas of the peatlands were shrub thicket, shrub heath fen, and streamside meadow.

Vegetation cover types that were concentrated on the bog proper, and were the most extensive types there, were shrub heath, wooded shrub heath, and forested bog (Table 9). The central to lower parts of the bog proper usually had cross-slope patterns of hollows (relatively wet) and ridges (relatively dry). In some cases the hollows contained secondary pools, but most often they were free of pools and were vegetated by moss lawns. The ridges were usually vegetated by shrub heath and wooded shrub heath. These patterned areas, confined to the eccentric units, ranged from 1% to 19% of the total peatland area and averaged 9.2%.

The peatlands contained large percentages of wooded (16%–78%; $\bar{x}$ = 60%) and semi-wooded (4%–27%; $\bar{x}$ = 16) areas. As indicated earlier, the proportion of wooded to semi-wooded was really much lower than the map data indicate. There was considerable variation in the relative abundances of vegetation types from one peatland to the next (Table 9), as can be seen on the plan maps.

Table 8. Vegetation types, abbreviations, and symbols used in text figures, tables, and appendices. Part I: specific types from TWINSPAN; Part II: cover and additional types.

I. *Specific types distinguished by TWINSPAN*, as they appear in text, some text tables and figures. For each type and its abbreviation, modifiers are given in parentheses. The order of listing follows the trophic alignment indicated by CCA, starting with the most oligotrophic type (Fig. 16b).

	Vegetation type name	Abbreviation	Symbol	No. of relevés
1.	Mud bottom (*Cladopodiella/Utricularia*)	MB (Cl/U)		3
2.	Moss lawn (*Chamaedaphne/Rhynchospora/ Eriophorum*)	ML (Ch/Ry/E)		14
3.	Shrub heath (*Sphagnum/ Eriophorum*)	SH (Sg/E)		12
4.	Moss lawn (*Carex oligosperma)*	ML (C)		1
5.	Moss lawn (wet; *Sphagnum cuspidatum*)	ML (Sgc)		2
6.	Wooded shrub heath (*Sphagnum/Eriophorum*)	WSH (Sg/E)		7
7.	Wooded shrub heath (moss)	WSH (m)		7
8.	Shrub heath	SH		2
9.	Shrub heath fen (*Sphagnum*)	SH-F (Sg)		4
10.	Shrub heath/wooded shrub heath	SH/WSH		3
11.	Forested bog (*Picea*/bryophyte)	FB (P/b)		4
12.	Open fen (*Carex oligosperma/ Sphagnum magellanicum*)	F (C/Sgm)		2
13.	Wooded shrub heath fen (*Rhododendron*/bryophyte)	WSH-F (R/b)		1
14.	Wooded shrub heath fen (*Sphagnum/Carex trisperma*)	WSH-F (Sg/C)		1
15.	Shrub thicket/open wooded fen (*Nemopanthus/Carex trisperma/ Viburnum cassinoides/Picea*)	ST/OWF (N/C/Vc/P)		1
16.	Low shrub thicket fen (*Rhododendron*)	LST (R)		4
17.	Shrub thicket/open wooded fen (*Sphagnum* spp./*Nemopanthus/ Carex trisperma*)	ST/OWF (Sg/N/C)		5

continued

Table 8. Continued

	Vegetation type name	Abbreviation	Symbol	No. of relevés
18.	Low shrub thicket/open wooded fen (*Sphagnum recurvum* aggr./ *Rhododendron/Ledum*)	LST/OWF (Sgr/R/L)	⬘	3
19.	Shrub thicket/open wooded fen (*Sphagnum recurvum* aggr./ Carex trisperma)	ST/OWF (Sgr/C)	⬙	3
20.	Shrub thicket fen (*Sphagnum girgensohnii*)	ST (Sgg)	△	1
21.	Streamside meadow fen (*Carex* spp./*Calamogrostis canadensis*)	SM (C/Ca)	△ (F)	1
22.	Shrub thicket/open mixed wooded fen (*Alnus*)	ST/OMWF (A)	◇	4

II. Vegetation cover types and additional vegetation types, as used in some text tables and on the plan maps:

Mud bottom	MB
Shrub heath	SH
Bog shrub heath	bog-SH
Shrub heath fen	SH-F or fen-SH
Moss lawn	ML
Chamaedaphne moss lawn	MC or Ch-ML
Wooded shrub heath	WSH
Wooded shrub heath fen	WSH-F
Forested bog	FB
Fen and open fen	F
Sedge fen	SF
Shrub thicket (fen)	ST
Wooded fen	WF
Open wooded fen	OWF
Gymnosperm wooded fen	GWF or Con WF
Angiosperm wooded fen	AWF or Hard WF
Mixed wooded fen	MWF
Streamside meadow (fen)	SM
Pattern	P
Hardwood (Angiosperm trees)	H
Sedge	S
Red maple (*Acer rubrum*)	RM
Upland (non-wetland)	U
Drainage ditch	DD

Table 9. Vegetation cover types in individual peatlands, as percentage of plan-mapped area. Specific types of wooded fen (GWF, AWF, MWF) were mapped only at some peatlands. In such cases the specific types were combined into WF for this table. See Table 8 for definitions of vegetation abbreviations. See Table 3b for full name of each peatland. Patt = patterned area of peatland.

Short name	FB	WSH	SH	Ch-ML	ML	SH/S/[a] ML	MB	WF	OWF[b]	ST[c]	SH-F[i]	SM	Patt	Tot-F	Tot-W[j]	Tot-SW[k]	Tot-A[l]
									%								
Big Bog	12.7	9.0	2.2		0.5	0.8	0.1	39.6		17.3	14.5	2.6	6.0	74.0	52.3	26.3	314
Coffin Bog		7.2	6.0		1.0	0.6		76.5	5.2	3.0	0.3		10.7	85.0	76.5	15.4	225
Cold Stream	13.8	8.1	4.1			0.9		39.3	3.8	11.7	6.2	11.7	10.3	72.7	53.1	23.6	1672
Crossuntic Stream		5.5	3.3		0.3		0.1	77.7	0.8	1.7	6.0		2.4	86.2	77.7	8.0	383
Elevenmile Lake	0.2	4.0	8.6		1.6			77.0	2.6	3.5	1.9		1.0	85.0	77.2	10.1	160
Flinn Pond (N. unit)	32.8	11.2	10.8		0.8			38.6			5.8		9.2	44.4	71.4	11.2	77
Flinn Pond (S. unit)	6.8	3.2	2.9		0.4			60.7	1.6		18.1		2.9	80.4	67.5	4.8	119
Hatham Bog	0.4	14.5	31.0	12.6	0.9	6.5	0.9	27.3	1.5				8.9	28.8	27.7	16.0	148
Inman Bog	25.1	12.0	18.4	15.7				20.1	1.6		6.8		12.5	28.5	45.2	13.6	190
Lambert Lake	0.4	9.5	10.8		2.4			57.4	0.1	5.6	13.1		16.6	76.2	57.8	15.2	209
Lindsey Brook	1.8	2.7	1.9	0.1	0.5			67.0	2.7	21.3	1.0		2.5	92.0	68.8	26.7	221
Macwahoc Stream[d]	1.5	13.7	14.2	5.6	1.8		1.8	14.6			42.8	1.3	17.4	58.7	16.1	13.7	103
Nollesemic Stream[e]	5.8	3.9	15.3		3.7			61.0		0.8			18.6	61.8	64.9	4.7	196
Smith Brook Dwtr[f]		15.9	25.8	9.3	0.7		0.4	26.0		4.7	14.1	2.8	?	44.8	26.0	20.6	211
Stetson Mountain	33.6	14.3	4.1	0.9	2.1			44.1	0.6				8.3	44.7	77.7	14.9	247
Vanceboro RR[g]		12.4	14.0		0.9			66.1		6.1			4.1	72.2	66.1	18.5	198
Wadleigh Bog	0.6	5.6	8.4		3.0		0.6	62.8	6.9	8.5	1.1		12.0	79.3	63.4	21.0	184
Mean[h]	7.7	8.6	9.9	2.3	1.3	0.6	0.2	52.0	1.8	5.3	7.0	1.0	9.2	67.2	59.6	15.7	—

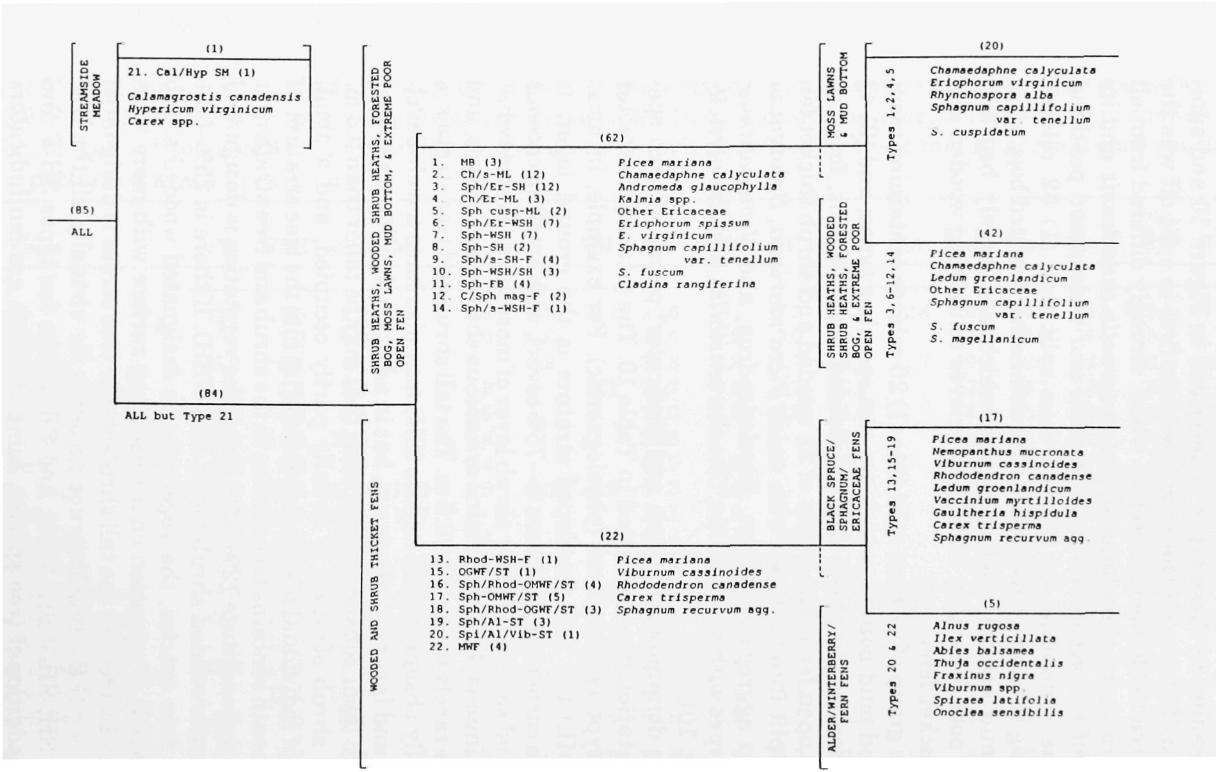
[a]S/Ch-ML & SH/S/ML [b]Includes WSH-F [c]Includes LST
[d]Only the mapped unit east of Macwahoc Str. and south of mouth of Juniper Br. [e]Only the mapped area south of Nollesemic Str.
[f]As mapped by Widoff and Ruffing (1984) [g]Only the mapped area containing the eccentric unit and its extension south of RR
[h]n = 15, not incl. Smith Brook Dwtr; average of N and S units of Flinn P. used as single entry [i]Includes SH/ML-F
[j]Tot-W = total % wooded: FB and WF [k]Tot-SW = total % semi-wooded: WSH, OWF, and ST [l]Tot-A = total area (ha) used for % calculations

Summary of relevé data

The 22 specific vegetation types in Table 8 were defined on the basis of the TWINSPAN results. The TWINSPAN sequence ("divisions") leading to these types is described in Figure 10 and summarized as follows. Of the 85 relevés, the first to split off was the single streamside meadow relevé which strongly differed from all the others in its abundance of *Calamogrostis canadensis* and its absence of Ericaceae and many typical and widespread peatland taxa. The remaining 84 relevés then split into (1) 62 relevés containing shrub heaths, wooded shrub heaths, forested bog, moss lawns, mud bottom, and open fen, which are largely bog and extreme poor fen types; and (2) 22 relevés containing wooded and shrub thicket fens.

The group of 62 then split into (1) 20 relevés containing moss lawns and mud bottom, which are wet open bog types; and (2) 42 relevés containing shrub heaths, wooded shrub heaths, forested bog, and open fens. The group of 22 wooded and shrub thicket fen relevés split into (1) types with much *Picea mariana*, *Sphagnum recurvum* aggregate, *Ledum*, *Rhododendron*, and *Nemopanthus*; and (2) types with much *Alnus*, *Onoclea sensibilis*, and *Ilex verticillata* (Fig. 10).

The dominant, common, and "indicator" plants of each specific vegetation type are listed in Table 10. The primary character of each type is structural (physiognomic). For example, in moss lawns (ML) the best-developed stratum is the ground layer. It consists a carpet of *Sphagnum* (>~75% cover), with small ericaceous shrubs and sedges. The low shrub layer of moss lawns is somewhat less continuous. It also contains ericaceous shrubs and sedges, and these are rarely taller than 0.5 m. The tall shrub and tree strata are essentially absent. Shrub heaths (SH) may also have a well-developed ground layer of *Sphagnum*, but in addition they have a robust low shrub layer consisting of ericads that may be taller than 0.5 m. The tall shrub stratum is usually partly occupied, and a small number of individual plants may extend up into the tree stratum. If a shrub heath contains tree species in the shrub and tree strata that collectively constitute 12%–25% cover, the vegetation is designated shrub heath/wooded shrub heath (SH/WSH). If there is 25%–50% cover by tree species, the vegetation is designated wooded shrub heath (WSH). Vegetation on a raised bog surface with more than 50% cover by trees in the tall shrub and/or tree strata is designated forested bog (FB). Black spruce accounts for virtually all the tree cover in SH, SH/WSH, WSH, and FB. In the fen types SH-F and WSH-F additional tree species, some of which are fen indicators (e.g., red maple), usually occur, and non-arboreal plant species indicators of fen are present, although ericaceous shrubs remain abundant in the low shrub stratum.



gure 10. First three TWINSPAN divisions, showing major groupings of vegetation types. Each branch (heaviest lines) of the dendrogram is renthetically labelled with the number of relevés it represents. For the second division (and Type 21 for the first division), abbreviations are given the numbered vegetation types. Following the abbreviations the number of relevés are parenthetically given. Only the type numbers are given for third division. Plant taxa that characterize the groupings are also given. See text, and particularly Tables 8 and 10, for meanings of vegetational breviations and additional details.

Table 10. Specific vegetation types, as defined by TWINSPAN. The types are arranged in approximate trophic order, starting with the most oligotrophic, as suggested by canonical correspondence analysis. For each type, the most abundant and characteristic taxa are given. After each taxon is its mean percentage cover (all strata combined) in the vegetation type (p = present at <~0.1%). Abbreviations are given for vegetation type modifiers. See Table 8 for full names of each vegetation type including modifiers. Modifier taxon abbreviations: A = *Alnus*; b = bryophyte; C = *Carex*; Ca = *Calamogrostis*; Ch = *Chamaedaphne*; Cl = *Cladopodiella*; E = *Eriophorum*; I = *Ilex*; L = *Larix*; m = moss; N = *Nemopanthus*; P = *Picea*; R = *Rhododendron*; Ry = *Rhynchospora*; Sg = *Sphagnum*; Sgc = *S. cuspidatum*; Sgg = *S. girgensohnii*; Sgm = *S. magellanicum*; Sgr = *S. recurvum* aggregate; U = *Utricularia*; V = *Viburnum*; Vb = *Viburnum cassinoides*. n = number of relevés. * = TWINSPAN indicator taxon.

1. Mud bottom (Cl/U) (n = 3):

Cladopodiella fluitans	25.0
Utricularia cornuta	21.2
Rhynchospora alba	9.5
Sphagnum cuspidatum	5.0
Vaccinium oxycoccos	2.0
Drosera rotundifolia	2.0
Chamaedaphne calyculata	1.3

2. Moss lawn (Ch/Ry/E) (n = 14):

Sphagnum capillifolium var. *tenellum* (= *Sphagnum rubellum*)	73.7
Chamaedaphne calyculata	49.3
Rhynchospora alba	17.0
Eriophorum spissum	8.5
Vaccinium oxycoccos	6.7
Eriophorum virginicum	6.1
Kalmia angustifolia	5.8
Sphagnum fuscum	3.5
Andromeda glaucophylla	2.8
Picea mariana	2.2
Sarracenia purpurea	1.7
Sphagnum magellanicum	1.4
Drosera rotundifolia	1.3

3. Shrub heath (Sg/E) (n = 12):

Chamaedaphne calyculata	44.7
Sphagnum capillifolium var. *tenellum*	39.4
Kalmia angustifolia	23.0

Sphagnum fuscum	18.8
Eriophorum spissum	9.1
Ledum groenlandicum	7.9
Cladina rangiferina	7.0
Eriophorum virginicum	5.5
Vaccinium oxycoccos	4.7
Picea mariana	4.4
Andromeda glaucophylla	4.1
Carex pauciflora	3.0
Mylia anomala	0.3

4. Moss lawn (C) (n = 1):

Sphagnum capillifolium var. *tenellum*	62.2
Carex oligosperma	62.2
Sphagnum magellanicum	13.2
Vaccinium oxycoccos	2.0
Chamaedaphne calyculata	2.0
Andromeda glaucophylla	2.0

5. Moss lawn (Sgc) (n = 2):

**Sphagnum cuspidatum*	87.2
Eriophorum virginicum	6.7
Chamaedaphne calyculata	1.1
Rhynchospora alba	1.0
Drosera intermedia	0.1

6. Wooded shrub heath (Sg/E) (n = 7):

Picea mariana	39.0
Sphagnum capillifolium var. *tenellum*	30.2
Kalmia angustifolia	16.6
Sphagnum fuscum	14.4
Chamaedaphne calyculata	13.4
Ledum groenlandicum	11.9
Eriophorum spissum	9.6
Cladina rangiferina	6.0
Sphagnum recurvum aggregate	5.8
Carex trisperma	5.5
Sphagnum magellanicum	4.6
Andromeda glaucophylla	4.1
Pleurozium schreberi	2.0
Sphagnum capillifolium (not var. *tenellum*)	1.9
Ptilidium ciliare	1.9
Mylia anomala	0.1

7. Wooded shrub heath (m) (n = 7):

Picea mariana	30.0
Sphagnum fuscum	20.2
Ledum groenlandicum	13.6
Kalmia angustifolia	10.0
Pleurozium schreberi	7.7
Chamaedaphne calyculata	6.2
Nemopanthus mucronata	4.1
Rhododendron canadense	4.1
Gaylussacia baccata	3.8
Sphagnum capillifolium var. *tenellum*	2.8
Cladina rangiferina	2.6
Sphagnum recurvum aggregate	2.2
Vaccinium myrtilloides	2.2
Vaccinium oxycoccos	1.2
Dicranum undulatum & *D.* spp.	1.0
Kalmia polifolia	0.7
Sphagnum magellanicum	0.6

8. Shrub heath (n = 2):

Gaylussacia baccata	30.8
Chamaedaphne calyculata	13.2
Kalmia angustifolia	13.2
Ledum groenlandicum	7.6
Picea mariana	6.9
**Sphagnum magellanicum*	6.7
Rhododendron canadense	6.6
Sphagnum fuscum	2.0
Dicranum spp.	2.0
Sphagnum capillifolium var. *tenellum*	2.0

9. Shrub heath fen (Sg) (n = 4):

Chamaedaphne calyculata	31.1
Sphagnum imbricatum	15.4
Sphagnum magellanicum	13.4
Sphagnum recurvum aggregate	13.4
Carex trisperma	9.1
Ledum groenlandicum	7.6
Rhododendron canadense	7.1
Smilacina trifolia	6.6
Kalmia angustifolia	4.8
Andromeda glaucophylla	4.4
Sphagnum fuscum	4.3
Picea mariana	4.0
Nemopanthus mucronata	3.8

Sphagnum capillifolium (not var. *tenellum*)	3.3
Eriophorum virginicum	3.3
Scheuchzeria palustris	3.3
Alnus rugosa	0.5

10. Shrub heath/wooded shrub heath (n = 3):

Rhododendron canadense	24.2
Picea mariana	14.1
Kalmia angustifolia	13.2
Chamaedaphne calyculata	9.5
Sphagnum fuscum	5.7
Cladina rangiferina	5.1
Gaylussacia baccata	4.4
Ledum groenlandicum	2.0
Dicranum spp.	2.0
Sphagnum magellanicum	1.4
Vaccinium oxycoccos	1.3
Nemopanthus mucronata	0.1
Kalmia polifolia	0.1
Drosera rotundifolia	0.1

11. Forested bog (P/b) (n = 4):

Picea mariana	62.9
Bazzania trilobata	22.5
Carex trisperma	15.5
Vaccinium myrtilloides	10.1
Dicranum undulatum & *D.* spp.	6.6
Ledum groenlandicum	4.3
Cladina rangiferina	4.3
Sphagnum capillifolium var. *tenellum*	3.9
Ptilidium ciliare	3.8
Rhododendron canadense	3.8
Sphagnum fuscum	3.8
Nemopanthus mucronata	3.8
Gaylussacia baccata	3.8
Chamaedaphne calyculata	1.0
Kalmia angustifolia	0.6
Sphagnum magellanicum	0.6
Vaccinium oxycoccos	0.1
Drosera rotundifolia	0.1

12. Open fen (C/Sgm) (n = 2):

**Carex oligosperma*	87.2
Sphagnum magellanicum	50.2
Andromeda glaucophylla	6.8

Myrica gale	6.6
Chamaedaphne calyculata	1.1
Thelypteris palustris	1.0
Iris versicolor	0.1
Osmunda regalis	0.1
Onoclea sensibilis	p

13. Wooded shrub heath fen (R/b) (n = 1):

Picea mariana	17.2
Rhododendron canadense	15.2
Bazzania trilobata	13.2
Dicranum undulatum	13.2
Ptilidium ciliare	13.2
Vaccinium myrtilloides	2.2
Kalmia angustifolia	2.0
Gaultheria hispidula	2.0
Cladonia cristatella	2.0
Sphagnum capillifolium (not var. *tenellum*)	0.2
Sphagnum fuscum	0.2

14. Wooded shrub heath fen (Sg/C) (n = 1):

Sphagnum recurvum aggregate	36.3
Ledum groenlandicum	36.3
Carex trisperma	36.3
Picea mariana	28.4
Andromeda glaucophylla	13.2
Kalmia angustifolia	13.2
Sphagnum magellanicum	13.2
Larix laricina	4.0
Eriophorum spissum	2.0
Carex pauciflora	2.0
Pleurozium schreberi	2.0
Rhododendron canadense	2.0
Sphagnum capillifolium (not var. *tenellum*)	2.0
Sphagnum capillifolium var. *tenellum*	2.0
Vaccinium oxycoccos	2.0

15. Shrub thicket/open wooded fen (N/C/Vc/P) (n = 1):

Nemopanthus mucronata	49.5
Carex trisperma	36.3
Viburnum cassinoides	26.4
Picea mariana	26.4
Rhododendron canadense	13.4
Gaylussacia baccata	13.2

Sphagnum recurvum aggregate	13.2
Amelanchier sp.	2.0
Bazzania trilobata	2.0
Chamaedaphne calyculata	2.0
Coptis groenlandica	2.0
Cornus canadensis	2.0
Dicranum spp.	2.0
Gaultheria procumbens	2.0
Kalmia angustifolia	2.0
Ledum groenlandicum	2.0
Maianthemum canadense	2.0
Myrica gale	2.0
Pleurozium schreberi	2.0
Vaccinium corymbosum	2.0
Vaccinium myrtilloides	2.0
Vacciunium oxycoccos	2.0
Acer rubrum	0.4
Sphagnum magellanicum	0.2

16. Low shrub thicket fen (R) (n = 4):

Rhododendron canadense	46.3
Sphagnum recurvum aggregate	28.3
Chamaedaphne calyculata	12.4
Aronia floribunda	6.6
Sphagnum magellanicum	4.8
Kalmia angustifolia	4.4
Ledum groenlandicum	4.3
Sphagnum capillifolium	3.8
Myrica gale	3.4
Picea mariana	3.3
Vaccinium corymbosum	3.3
Carex stricta	1.1

17. Shrub thicket/open wooded fen (Sg/N/C) (n = 5):

Nemopanthus mucronata	29.1
Carex trisperma	27.3
Sphagnum magellanicum	25.3
Sphagnum recurvum aggregate	25.3
Vaccinium myrtilloides	10.7
Picea mariana	10.4
Sphagnum girgensohnii	9.9
Viburnum cassinoides	8.2
Osmunda cinnamomea	8.1
Ledum groenlandicum	6.5
**Gaultheria hispidula*	6.5

Alnus rugosa	5.3
Acer rubrum	4.4
Pleurozium schreberi	3.9
Kalmia angustifolia	3.5
Coptis groenlandica	3.1
Carex cf. *stricta*	2.6
Thuja occidentalis	0.5

18. Low shrub thicket/open wooded fen (Sgr/R/L) (n = 3):

Sphagnum recurvum aggregate	70.1
Rhododendron canadense	54.4
Larix laricina	21.2
Eriophorum cf. *tenellum*	12.1
Myrica gale	5.1
Sphagnum capillifolium	5.1
Carex trisperma	5.1
Sphagnum magellanicum	5.1
Nemopanthus mucronata	4.5
Ledum groenlandicum	4.4
Sphagnum papillosum	4.4
Chamaedaphne calyculata	2.0
Picea mariana	1.5
Smilacina trifolia	1.4
Vaccinium oxycoccos	1.4
Vaccinium corymbosum	1.3
**Dicranum* spp.	0.8
Vaccinium myrtilloides	0.1
Pleurozium schreberi	0.1

19. Shrub thicket/open wooded fen (Sgr/C) (n = 3):

Sphagnum recurvum aggregate	53.1
Carex trisperma	32.6
Rhododendron canadense	17.9
Viburnum cassinoides	17.9
Larix laricina	13.5
Alnus rugosa	10.8
Chamaedaphne calyculata	9.5
Smilacina trifolia	9.5
Ledum groenlandicum	8.9
Acer rubrum	5.1
Sphagnum magellanicum	4.5
Calla palustris	4.5
Eriophorum angustifolium	4.4
Ilex verticillata	2.1
Kalmia angustifolia	1.3
Aronia floribunda	0.7

20. Shrub thicket fen (Sgg) (n = 1):

Sphagnum girgensohnii	36.3
Spiraea latifolia	15.2
Alnus rugosa	13.4
Carex stricta	13.2
Viburnum cassinoides	2.2
Sphagnum magellanicum	2.0
Carex spp.	2.0
Viburnum recognitum	2.0

21. Streamside meadow fen (C/Ca) (n = 1):

Carex spp. including *C. stricta*	49.5
**Calamogrostis canadensis*	26.4
Equisetum fluvatile	2.0
Lysimachia terrestris	2.0
Potentilla palustris	2.0
**Hypericum virginicum*	2.0

22. Shrub thicket/open mixed wooded fen (A) (4):

Alnus rugosa	38.3
Sphagnum recurvum	15.4
Abies balsamea	13.7
Ilex verticillata	11.6
Onoclea sensibilis	9.2
Acer rubrum	7.7
Thuja occidentalis	7.7
Carex trisperma	6.7
Fraxinus nigra	6.7
Thuidium delicatulum	3.4
Plagiomnium ellipticum	3.4
Picea mariana & P. rubens	3.4
Osmunda cinnamomea	3.3
Sphagnum capillifolium var. *capillifolium*	3.3
Cornus canadensis	1.1
Bazzania trilobata	1.1
Rubus hispidus	0.6
Gaultheria hispidula	0.2
Viburnum cassinoides	0.2
Pleurozium schreberi	0.2
Trientalis borealis	0.2

The distinction between bog and fen vegetation is mainly floristic. However, major types of fens are primarily defined on a structural basis. Open fen (F) has few if any plants above the low shrub stratum, and that stratum is dominated by plants shorter than 0.5 m and usually contains an abundance of sedges. Shrub thicket fens (ST) have a well-developed tall shrub stratum, largely consisting of non-ericaceous species (although *Rhododendron canadense* may be abundant). In low shrub thicket fen (LST) the low shrub stratum is the best developed one, although the shrubs tend to be tall (0.7–1.5 m) for that stratum. *Rhododendron canadense* usually is a dominant. Open wooded fens (OWF) have an open or discontinuous tree stratum ranging from 15% to 50% cover and usually have a shrub thicket understory (ST/OWF). Streamside meadow (SM) virtually lacks trees, has a poorly developed ground stratum, and is dominated by sedges, grasses, and non-ericaceous shrubs (usually 0.5–1.0 m tall).

Each of these physiognomic vegetation types can be divided into more specific types (as by TWINSPAN) on a floristic basis. The specific types are designated by modifiers in parentheses, for example, moss lawn (*Chamaedaphne/Rhynchospora/Eriophorum*), abbreviated ML (Ch/Ry/E). Twenty-two specific types have been defined for Maine's eccentric bogs (Tables 8 & 10). Some of these types are more reliably established than others, depending on the number of relevés on which they are based. A more definitive classification of the vegetation types of all types of peatlands in Maine including eccentric bogs and based on several hundred relevés is being developed.

In addition to the above physiognomic and floristic differences between vegetation types, there are differences in microrelief of the peatland surface. Some types lack well-developed hummocks and hollows and have very little microrelief. Types with microrelief <~0.2 m include moss lawns, mud bottom, streamside meadow, open fen, low shrub thicket, and forested bog. Types with hummocks and hollows associated with root masses of woody plants and with microrelief generally 0.3 to 0.4 m include shrub thicket fens and open wooded fens. Vegetation types with even greater microrelief, generally 0.3–0.6 m but in exceptional cases to almost a meter, include wooded shrub heaths and shrub heaths. Apart from their occurrence on ridges and in troughs of the eccentric bog units, respectively, wooded shrub heaths and shrub heaths usually have a well-developed non-linear mosaic of hummocks and hollows (lacking pools). These hummocks and hollows are of the well-known type (Tansley 1949; Moore and Bellamy 1974), with greatest abundance of woody plants on the hummocks. The hummocks have different associations of *Sphagnum* species than the hollows (e.g., *S. fuscum* is largely restricted to the hummocks). The positions of the hummocks and hollows appear to persist for long periods of time (centuries-millennia) as bogs grow higher. The causes of this persistent microtopographic pattern are undoubtedly biotic/hydrologic, but specific explanations are still being debated (Moore and Bellamy 1974; Gore 1983a; Barber 1981; Clymo in press).

Major patterns of variance in the vegetation data

An ordination of the vegetation samples (relevés) along the first two DECORANA axes indicates the degrees of similarity (or difference) between the samples. On the ordination plot (Fig. 11), the samples are symbolized according to specific vegetation type as defined by TWINSPAN (Tables 8 & 10). The TWINSPAN-defined types are mostly separated into clusters on the DECORANA ordination.

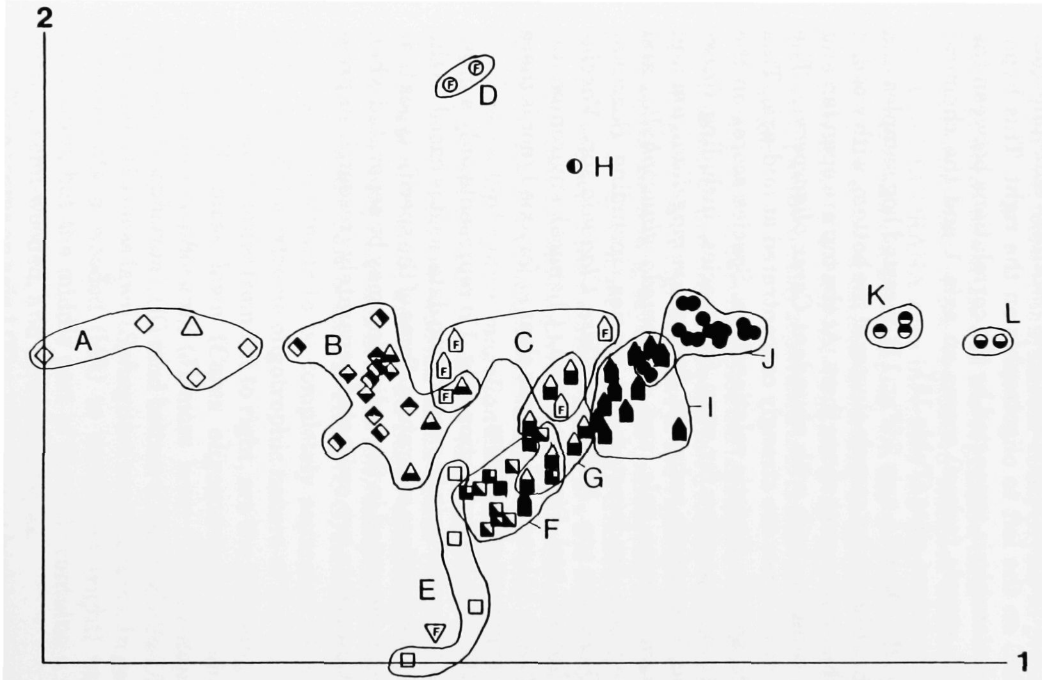
Along axis 1, shrub thicket fen (*Sphagnum girgensohnii*) and shrub thicket/open mixed wooded fen (*Alnus*) relevés occur on the far left (group A in Fig. 11). Just to the right of them is a group (B) of samples containing several types (numbered 15 to 19 in Tables 8 and 10) of shrub thicket fens and shrub thicket/open wooded fens. Next, and toward the middle of axis 1, are the wooded shrub heath fen (*Rhododendron*/bryophyte; *Sphagnum*/*Carex trisperma*) and shrub heath fen (*Sphagnum*) samples (C), and open fen (*Carex oligosperma*/*Sphagnum magellanicum*) samples (D). At about the same position on axis 1 are the forested bog (*Picea*/bryophyte) samples (E), and the wooded shrub heath (moss), shrub heath/wooded shrub heath, and shrub heath samples (F). The wooded shrub heath (*Sphagnum*/*Eriophorum*) samples (G) also occur along the middle part of axis 1. These (C-G) fen and bog vegetation types are too similar to be completely separated along axis 1, a reflection of the extreme oligotrophic nature of the fens. Next and to the right, in order from left to right, are the following vegetation groups: (H) moss lawn (*Carex oligosperma*); (I) shrub heath (*Sphagnum*/*Eriophorum*); (J) moss lawn (*Chamaedaphne*/*Rhynchospora*/*Eriophorum*); (K) mud bottom (*Cladopodiella*/*Utricularia*); and finally (L) moss lawn (*Sphagnum cuspidatum*). In general, axis 1 represents a wooded (left) to unwooded (right) vegetational continuum, but the middle part of the axis contains a mixture of wooded, semi-wooded, and unwooded types.

Taxa scores on axis 1 (Fig. 11) are most highly positive for open bog species including *Sphagnum capillifolium* var. *tenellum*, *S. cuspidatum*, *Eriophorum virginicum*, *Rhynchospora alba*, *Vaccinium oxycoccos*, *Drosera* spp., and *Cladopodiella fluitans*, and most negative for wooded fen species including *Dryopteris cristata*, *Onoclea sensibilis*, *Plagiomnium ellipticum*, *Rubus hispidus*, *Abies balsamea*, and *Fraxinus nigra*.

While DECORANA is based entirely on the vegetation data, the continua along the axes can often be interpreted in terms of environmental gradients. DECORANA axis 1 appears to largely parallel an environmental gradient from *relatively* eutrophic (but still poor fen) on the left to oligotrophic on the right. This hypothesized relationship is supported by the correlations between the DECORANA sample (relevé) scores on axis 1 and the chemical results for the relevé sites (Table 11).

Along DECORANA axis 2 (Fig. 11), forested bog samples and a wooded shrub heath fen sample cluster at the bottom, with wooded shrub heath samples next above them. At the top are open fen and moss lawn samples, both with abundant *Carex oligosperma*. The other vegetation types are strongly concentrated at mid-axis. This axis reflects specific floristic relationships. Species scores on the axis are strongly positive for open fen species, including *Carex oligosperma*, *Thelypteris palustris*, *Sphagnum magellanicum* and *S. papillosum*, *Myrica gale*, and *Andromeda glaucophylla*, and strongly negative for forested bog species, including *Bazzania trilobata*, *Dicranum* spp., *Ptilidium ciliare*, *Cladonia* spp., *Vaccinium myrtilloides*, and *Picea mariana*. Chemical environmental correlates (Table 11) are not nearly as clear as for axis 1, nor is there an obvious explanation for them.

The DECORANA ordination (Fig. 11) represents only a gross summary of the patterns in the vegetation data, as it is based on the entire data set regardless of stratum. Some of the specific types that are not clearly separated in the ordination may be separated when the vegetation strata are ordinated separately (research in progress).



ıre 11. Ordination of relevés (vegetation samples) along the first two DECORANA axes. Each relevé is represented by a symbol indicating its :tation type as determined by TWINSPAN. Meaningful groups of vegetation types are indicated on the ordination: A = shrub thicket/open mixed ded fen (*Alnus*), and shrub thicket fen (*Sphagnum girgensohnii*); B = other shrub thicket fen and shrub thicket/open wooded fen types; C = shrub :h fen, wooded shrub heath fen (*Sphagnum/Carex trisperma*), and two wooded shrub heath (*Sphagnum/Eriophorum*) relevés; D = open fen; E = sted bog (nearby single outlier, up-side-down triangle with F is a wooded shrub heath fen [*Rhododendron*/bryophyte] relevé); F = wooded shrub :h and shrub heath types; G = wooded shrub heath types, and one shrub heath fen relevé; H = moss lawn (*Carex oligosperma*); I = shrub heath, and moss lawn (*Chamaedaphne/Rhynchospora/Eriophorum*) relevés; J = moss lawn (Ch/Ry/E), and a shrub heath relevé; K = mud bottom; and L = moss ıawn (*Sphagnum cuspidatum*). See text and particularly Tables 8 and 10 for definitions of symbols and descriptions of vegetation types.

Table 11. Correlations between vegetation sample (relevé) scores on the first two DECORANA axes and interstitial water chemistry at the relevés. $p < 0.001$ = ***; p 0.001-0.01 = **; p >0.01-0.05 = *.

Pearson product moment correlation coefficients:

	Axis 1	Axis 2
Calcium	-0.599***	0.204
Potassium	-0.168	-0.074
Magnesium	-0.558***	0.186
Phosphorus	-0.336**	-0.346**
Aluminum	-0.271*	0.048
Iron	-0.388**	0.187
Manganese	-0.311**	0.269*
Sodium	-0.450***	-0.031
Silicon	-0.484***	0.120
Zinc	-0.123	0.156
Chlorine	-0.158	-0.058
Nitrate	-0.008	-0.053
Ammonia	-0.221	-0.025
Sulfate	-0.306**	0.001
Conductance	0.107	-0.291*
pH	-0.534***	0.115
DOC	0.063	-0.025

Spearman rank correlation coefficients:

	Axis 1	Axis 2
Calcium	-0.483***	0.265*
Potassium	-0.203	-0.034
Magnesium	-0.422***	0.287**
Phosphorus	-0.354**	-0.262*
Aluminum	-0.238*	0.112
Iron	-0.468***	0.129
Manganese	-0.465***	0.024
Sodium	-0.492***	-0.011
Silicon	-0.353**	0.082
Zinc	-0.172	0.118
Chlorine	-0.218	0.032
Nitrate	-0.037	0.012
Ammonia	-0.175	-0.156
Sulfate	-0.239*	-0.010
Conductance	0.129	-0.190
pH	-0.323**	0.120
DOC	0.033	0.102

Peat Interstitial Water Chemistry of Maine's Eccentric Bog Complexes[7]

General

The interstitial waters of the acrotelm of the eccentric bogs (including fen areas) were generally dilute and acidic (Table 12), reflecting two conditions: (1) bedrock and surficial geological deposits that are granitic and relatively insoluble, and (2) the ombrotrophic condition of a large percentage of the sites. Two variables of interest, Ca and pH (Figs. 12 and 13) have large majorities of very low values: less than 1.0 ppm and 5.0, respectively. These values are compared to those from bogs and fens in northern Minnesota (Fig. 14, modified from Glaser [1987]). None of the Maine values falls into the "Extremely Rich Fen" area marked on the Minnesota diagram. The three highest pH values from Maine are within the range of Minnesota's "Intermediate Rich Fen," but are at the very low end of the Ca scale for such fens. Overall, the Ca and pH values from Maine are most similar to the bog and poor fen sites of Minnesota.

In comparison to Sweden, most of the Maine pH values fall within the bog and extreme poor fen pH ranges, 3.7–4.2 and 3.8–5.0, respectively, as defined by Sjörs (1950). The same conclusion applies to comparisons of the Maine calcium values to those in Sweden (Gorham 1955).

Principal components analysis

The main sources of variance in the interstitial water chemistry can be inferred from the loadings of chemical variables on the first four principal components (factors) (Table 13). The first component, which explains 30% of the variance, has strongest positive loadings for pH and for chemical elements from geological/mineral soil sources, for example, Ca, Mg, Fe, Si, etc.

The second component explains an additional 11% of the variance. The strongest positive loadings are for DOC and conductance, and strongest negative loading is for pH. The association of low pH with high DOC, and the low (<0.25) loadings for sulfate and nitrate suggest that the low pH is largely due to organic rather than inorganic acids. This relationship is consistent with the findings of other investigators for bogs outside heavily industrialized areas (Gorham et al. 1985; Urban et al. 1987; Shotyk 1988; Kahl et al. 1989).

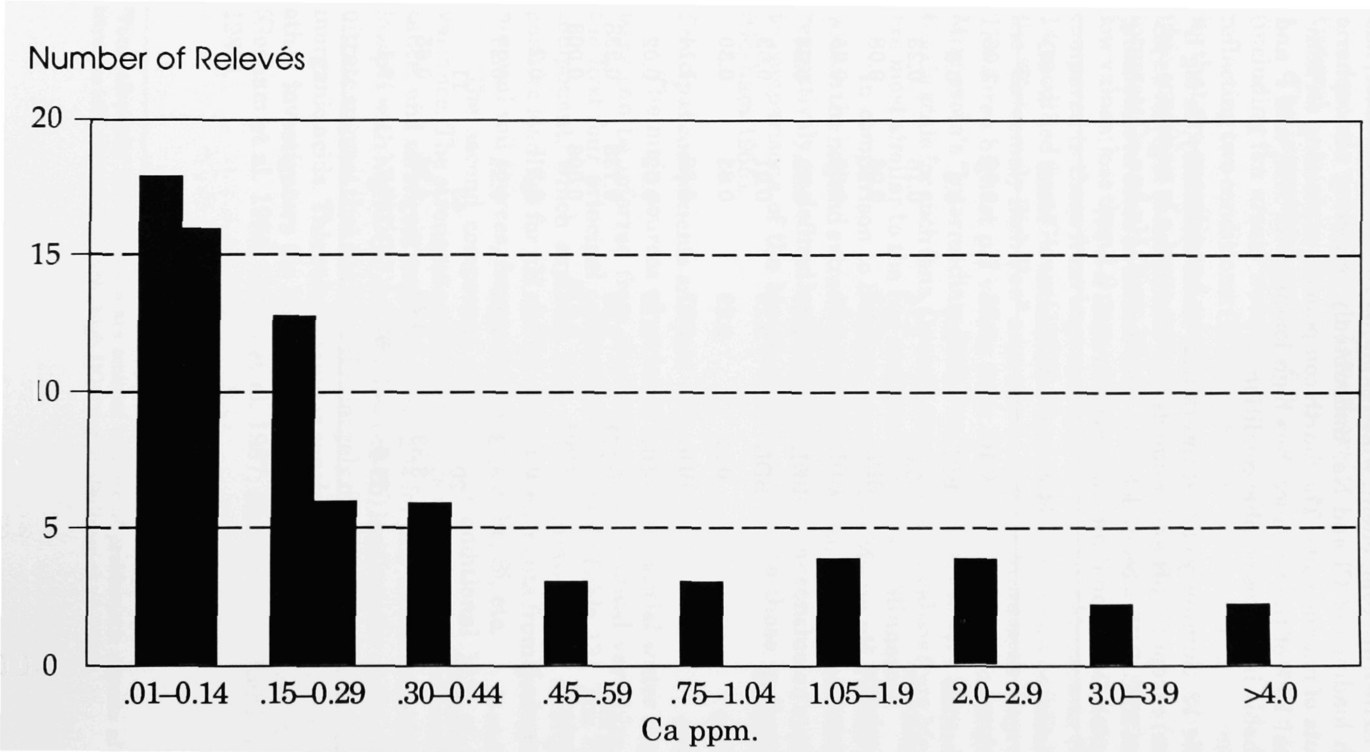
---

[7]Total alkalinity (ANC) results are omitted because of problematic aspects of the titration technique for low ANC/high DOC waters (Sullivan et al. 1989).

The third component, which explains 10% of the variance, has high loadings of Cl and Na, undoubtedly reflecting atmospheric inputs of marine salts. The fourth component, explaining an additional 10% of the variance, has high loadings for NH_4 and P and probably indicates trophic condition.

Table 12. Summary of peat interstitial water chemistry, in mg L^{-1} (ppm) except for pH and conductance. Conductance is given as µS/cm at 25°C. BDL = below detection limit (tallied as zeros in calculating means). Detection limits are given in text. n = 77.

Variable	Minimum	Maximum	Mean	+/- SD
Calcium	0.16	5.26	0.58	1.06
Potassium	BDL	2.0	0.3	0.3
Magnesium	0.02	1.74	0.16	0.23
Phosphorus	BDL	0.43	0.06	0.08
Aluminum	BDL	0.31	0.05	0.05
Iron	BDL	1.37	0.13	0.24
Manganese	BDL	0.19	0.01	0.03
Sodium	0.22	2.29	0.63	0.30
Silicon	BDL	6.37	0.86	1.14
Zinc	BDL	0.13	0.02	0.02
Chlorine	0.171	2.06	0.738	0.338
Nitrate-N	0.004	0.015	0.006	0.003
Ammonia-N	0.1	1.0	0.3	0.2
Sulfate-S	0.02	1.95	0.21	0.27
Conductance	20	75	43	11
pH	3.83	8.20	4.26	0.65
DOC	14.8	57.1	37.7	9.1



igure 12. Histogram of calcium concentrations in peat interstitial waters of relevés. The two lowest intervals are split into 0.01–0.07 and 0.08–0.14, nd 0.15–0.21 and 0.22–0.29.

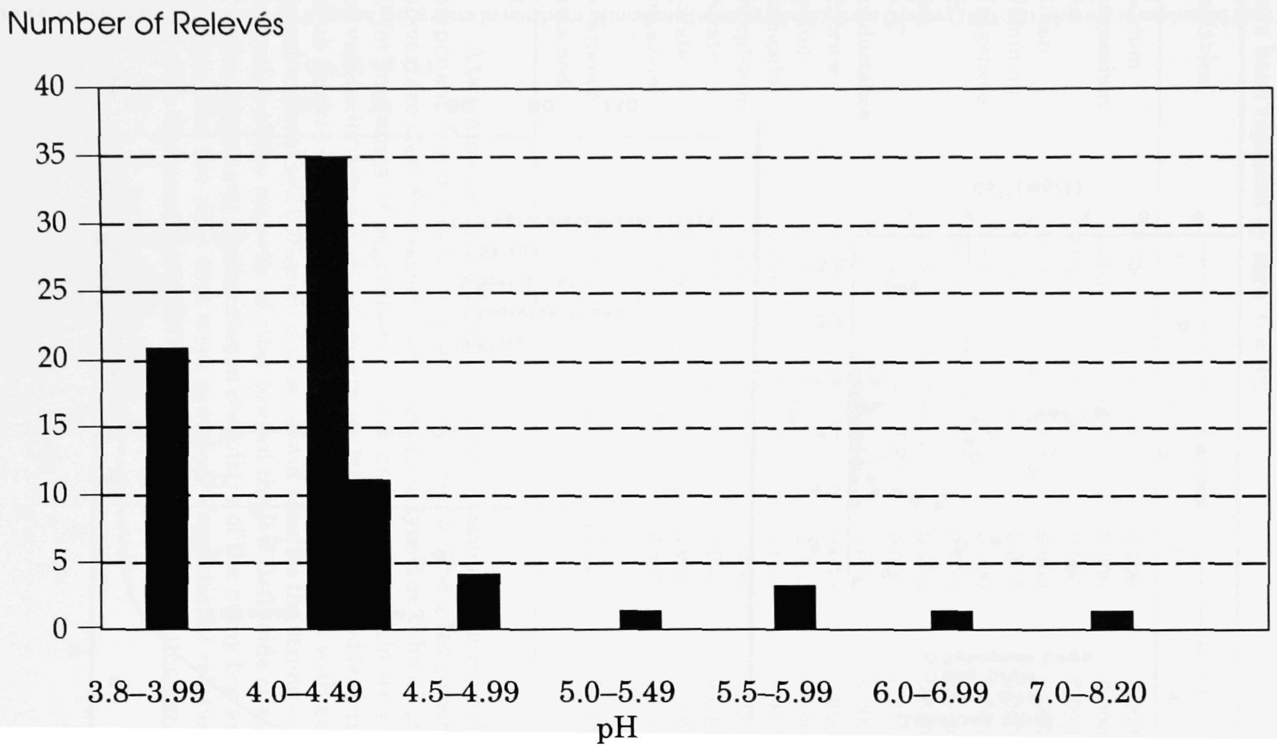
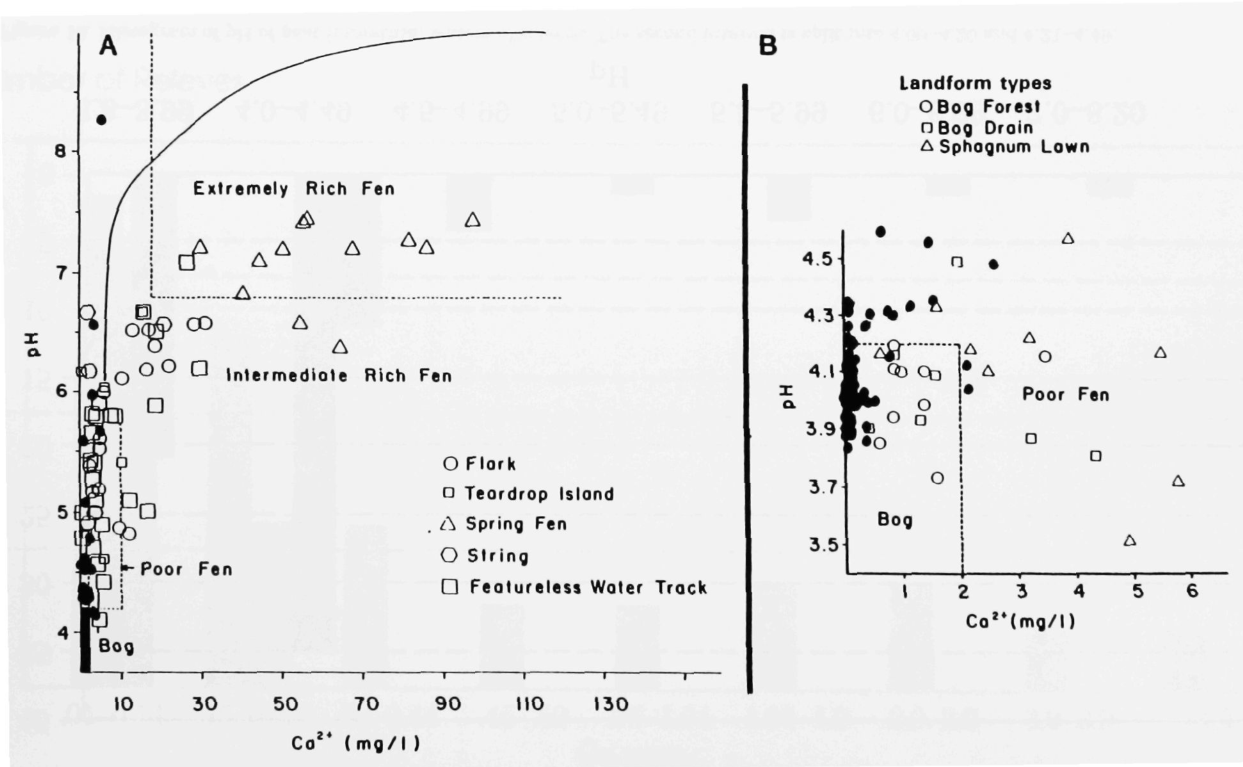


Figure 13. Histogram of pH of peat interstitial waters of relevés. The second interval is split into 4.00–4.20 and 4.21–4.49.



ure 14. Calcium and pH values for bog and fen waters in northern Minnesota (open symbols), from Glaser (1987:22) where it is explained that "The ıplete range of water samples is shown in (A), with the pH and calcium values for specific ranges defined by the dashed lines. The samples in the re restricted bog range are shown in (B)." For comparison, values for peat interstitial waters of Maine's eccentric bog complexes are given as blackened small circles (n = 77).

Table 13. Loadings of the chemical variables on the first four principal components (rotated factors). Loadings less than 0.2500 have been replaced by zero. n = 82.

Variables	Factors 1	2	3	4
Calcium	0.910	0.000	0.000	0.000
Magnesium	0.866	0.000	0.000	0.000
Iron	0.842	0.000	0.000	0.000
Silicon	0.841	0.000	0.000	0.000
Aluminum	0.668	0.289	0.000	0.000
Manganese	0.666	0.000	0.000	0.000
pH	0.607	-0.526	0.000	0.000
Zinc	0.552	0.481	0.000	0.000
DOC	0.000	0.810	0.000	0.275
Conductance	-0.258	0.639	0.000	-0.309
Chlorine	0.000	0.000	0.919	0.000
Sodium	0.545	0.000	0.706	0.000
Ammonia	0.000	0.000	0.000	0.917
Phosphorus	0.000	0.000	0.286	0.625
Nitrate	0.000	0.000	0.000	0.000
Sulfate	0.316	0.000	0.000	0.000
Potassium	0.000	0.376	0.441	0.306
% variance explained	29.782	11.129	10.353	9.818

A two-dimensional ordination of the site (sample) scores on the component 1 and 2 axes is given as Figure 15. The sites (mostly relevés) are identified according to vegetation type (see Tables 8 and 10 for meanings of vegetational types and symbols). On axis 1, bog vegetation types score relatively low, and open wooded fens and shrub thicket fens score high, indicating an association with geological/mineral soil influence. An important result is the strong concentration of the majority of sites toward the low (left) side of axis 1, indicating strong similarities in chemistry of the many bog and extreme poor fen sites that were sampled. Vegetational relationships with the second axis (DOC and organic acids) are unclear.

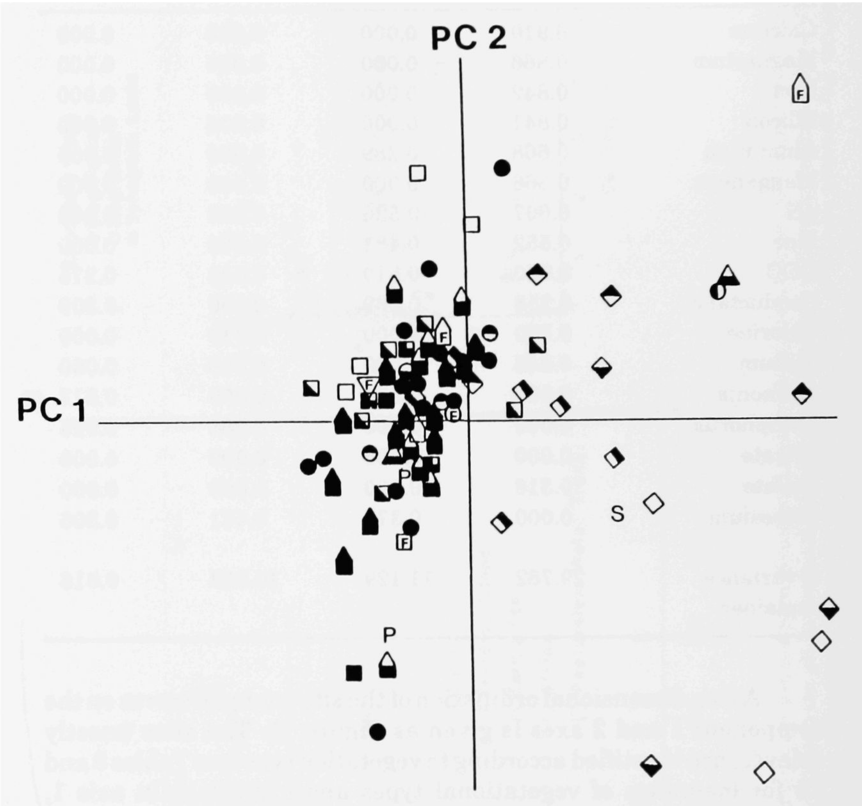


Figure 15. Ordination of water chemistry samples along the first two PCA axes. S = stream sample; P = secondary pool sample. All other samples are of peat interstitial water from relevés. Each of these is entered as a symbol indicating the vegetation type of the relevé, as determined by TWINSPAN. See Table 8 for definitions of symbols, and Table 10 and text for descriptions of vegetation types and for interpretation of vegetation/chemistry relationships.

Relationships between Flora, Vegetation, and Peat Interstitial Water Chemistry in Maine's Eccentric Bog Complexes

The results of canonical correspondence analysis (Table 14; Fig. 16) more directly show the relationships between the biological and environmental variables. The first two axes of the species-environment biplot (Fig. 16a) account for 40% of the variance (Table 14). This percentage is substantial for field data made up of so large a number of biological and chemical variables. As an aid to further interpretation of these statistics (Table 14) see ter Braak (1986).

On the biplot (Fig. 16a), bog species occur on the left and fen species on the right. The bog species are associated with highest values for conductance[8] and lowest values for pH and elements from mineral substrates. The fen species are associated with highest values for pH and elements from mineral substrates.

By comparing the CCA ordination of vegetation samples (relevés; Fig. 16b) with the biplot (Fig. 16a), the relationships of vegetation types (typology based largely on TWINSPAN) with both flora and chemistry are seen. The upper left to lower right arrangement of vegetation types along the dominant chemical gradient is striking. The lowest mineral concentrations are associated with the bog vegetation types: moss lawn (Ch/Ry/E), mud bottom (Cl/U), shrub heath (Sg/E), and wooded shrub heath (Sg/E). The highest mineral concentrations occur at streamside meadow fen (C/Ca) and at all types and combinations of shrub thicket fens and open wooded fens. The interstitial waters of wooded shrub heath (m), forested bog (P/b), shrub heath fen (Sg), and wooded shrub heath fens are intermediate. The overlap of these bog and fen types in the middle of the ordination results not only from the quantitative similarity of the vegetation types but also from the extreme low trophic state of those fens. That oligotrophic state is due largely to siliceous/granitic geology.

The CCA strongly confirms our earlier interpretations based on the DECORANA and PCA analyses. The major trends in the CCA ordinations indicate consistent interrelationships between vegetation, flora, and peat interstitial water chemistry. The main vegetational continuum follows an environmental gradient that appears to be a trophic gradient tied to degree of mineral input to the acrotelm.

---

[8]High conductances in bogs are partly due to high H^+ (low pH).

Table 14. Canonical coefficients and intraset correlations of chemical variables with the first two CCA axes, and percentage of variance accounted for by these axes of species-chemistry biplot (Fig. 16a)

	Canonical coefficients		Correlation coefficients	
	axis 1	axis 2	axis 1	axis 2
Ca	1.09	-0.44	0.85	-0.40
K	0.13	0.02	0.10	-0.24
Mg	0.62	1.02	0.92	-0.17
P	0.08	-0.17	0.16	-0.26
Al	-0.10	-0.05	0.19	-0.68
Fe	-0.60	0.00	0.33	-0.70
Mn	-0.25	-0.32	0.28	-0.55
Na	0.03	-0.42	0.36	-0.68
Si	0.17	-0.39	0.46	-0.68
Zn	-0.13	-0.03	0.21	-0.17
Cl	-0.02	0.03	0.08	-0.24
SO_4	-0.08	-0.19	0.36	-0.29
Conductance	0.24	-0.01	-0.20	0.17
pH	0.41	-0.06	0.88	-0.16
DOC	-0.22	-0.07	-0.17	-0.32

Percentage of variance accounted for by first two axes of species-chemistry biplot:

Axis 1	24.8
Axis 2	15.2

Origins and Patterns of Development of Maine's Eccentric Bog Complexes

Earlier we described an intensive study by Perkins (1985) on the origins and development of the southern eccentric bog unit at Smith Brook Deadwater, Maine. The present study differs from Perkins's in its extensive rather than intensive nature. The peat stratigraphy of 15 eccentric bogs was sampled to determine if generalizations could be made regarding origins and development of the peatland type in Maine. The results are sketchy for each site, both in terms of areal coverage and stratigraphic detail, but all told they lead to meaningful conclusions about Maine's eccentric bog complexes in general.

Assumptions regarding modern analogues

Ancient vegetation types were inferred from ancient peats by assuming that ancient vegetation/ancient peat relationships are the same as those observed in modern vegetation/modern peat. The modern relationships were determined by comparing present vegetation types with peat types immediately underlying them. Peats were sampled at the 6- to 10-inch (15- to 25-cm) depth. It was assumed that the vegetation hadn't changed appreciably since that peat was formed[9], although that may not always have been the case (e.g., peatlands occasionally burn, destroying upper peat and reducing populations of certain species like black spruce). This approach also assumes that decomposition (in this case, below 15–25 cm) of remains of some plant taxa has not been appreciably greater than the decomposition of others. It is well known, however, that differential decomposition does occur (Clymo 1983) and must be accounted for in reconstructions of past vegetational composition of peatlands. In this study only major peat types (not specific plant taxa) were used for inferring only the gross nature of ancient peatland ecosystems, so misinterpretations arising from the two simplistic assumptions (above) are probably not serious.

Modern analogue studies (Davis and Hu in prep.) at eccentric bogs and several other peatland types in Maine indicate that bog shrub heath forms peat rich in *Sphagnum* remains, with lesser, but appreciable, amounts of woody material, and little herbaceous material. Peat from bog wooded shrub heath is similar, but with somewhat greater amounts of woody material. Peat from forested bog has even more woody material (but still with appreciable amounts of *Sphagnum*). Moss lawn (various subtypes: Table 8) peats consist largely of *Sphagnum* remains, and contain less woody

---

[9] *Sphagnum* moss increment dating of 26 short cores from Maine bogs (Tolonen et al. 1988) indicated that the 15- to 25-cm peat depth dates 15 to 35 years before present.

Figure 16. Canonical correspondence analysis (CCA) ordinations along the first two CCA axes (CANOCO program of ter Braak 1987).

(a) CCA biplot, showing relationships of species scores and interstitial water chemistry. The relative lengths of the arrows indicate the importance of particular chemical variables in explaining the chemical variance in the data set. While the arrows begin at the origin, they may be visualized as extending in both directions beyond the origin, with relatively positive value in the direction of the arrow point, relatively negative value in the opposite direction. Numbered species are plotted according to their scores on the CCA axes. Relative positions of individual species along individual chemical gradients may be determined by drawing lines from species points to chemical vectors, perpendicular to vectors or their extensions on the opposite side of the origin. The collective orientation of the arrows and species scores is from upper left to lower right. 1 (box) = *Andromeda glaucophylla*, *Chamaedaphne calyculata*, *Cladina rangiferina*, *Eriophorum virginicum*, *E. spissum*, *Gaylussacia baccata*, *Sphagnum capillifolium* var. *tenellum*, *Vaccinium oxycoccos*; 2 (box) = *Kalmia angustifolia*, *K. polifolia*, *Picea mariana*, *Sphagnum cuspidatum*, *S. fuscum*; 3 (box) = *Carex oligosperma*, *C. pauciflora*, *Scheuchzeria palustris*; 4 = *Utricularia cornuta*; 5 = *Cladopodiella fluitans*; 6 = *Rhynchospora alba*; 7 = *Sphagnum magellanicum*; 8 = *Gaultheria hispidula*; 9 = *Ledum groenlandicum*; 10 = *Eriophorum angustifolium*; 11 = *Rhododendron canadense*; 12 = *Carex trisperma*; 13 = *Smilacina trifolia*; 14 = *Sphagnum recurvum* aggr.; 15 = *Viburnum cassinoides*; 16 = *Aronia floribunda*; 17 = *Calamogrostis canadensis*; 18 = *Larix laricina*; 19 = *Carex stricta*; 20 = *Osmunda cinnamomea*; 21 = *Ilex verticillata*; 22 = *Iris versicolor*; 23 = *Hypericum virginicum*; 24 = *Acer rubrum*; 25 = *Thuidium delicatulum*; 26 = *Alnus rugosa*; 27 = *Thuja occidentalis*; 28 = *Osmunda regalis*; 29 = *Onoclea sensibilis*; 30 = *Plagiomnium ellipticum*; 31 = *Rubus hispidus*; 32 = *Abies balsamea*; 33 = *Fraxinus nigra*.

(b) Ordination of vegetation sample scores. Scores are entered as symbols (defined in Table 8) indicating the vegetation type of the relevé. Vegetation types were determined by TWINSPAN (Tables 8 and 10). The diagram shows the relationships of vegetation types to the CCA axes and the overall trend of the data from upper left (bog sites) to lower right (fen sites). This trend parallels the main one in (a), indicating consistent interrelationships between vegetation, species, and chemistry. The main vegetational continuum follows the main environmental gradient which is a trophic gradient (see text and Table 14).

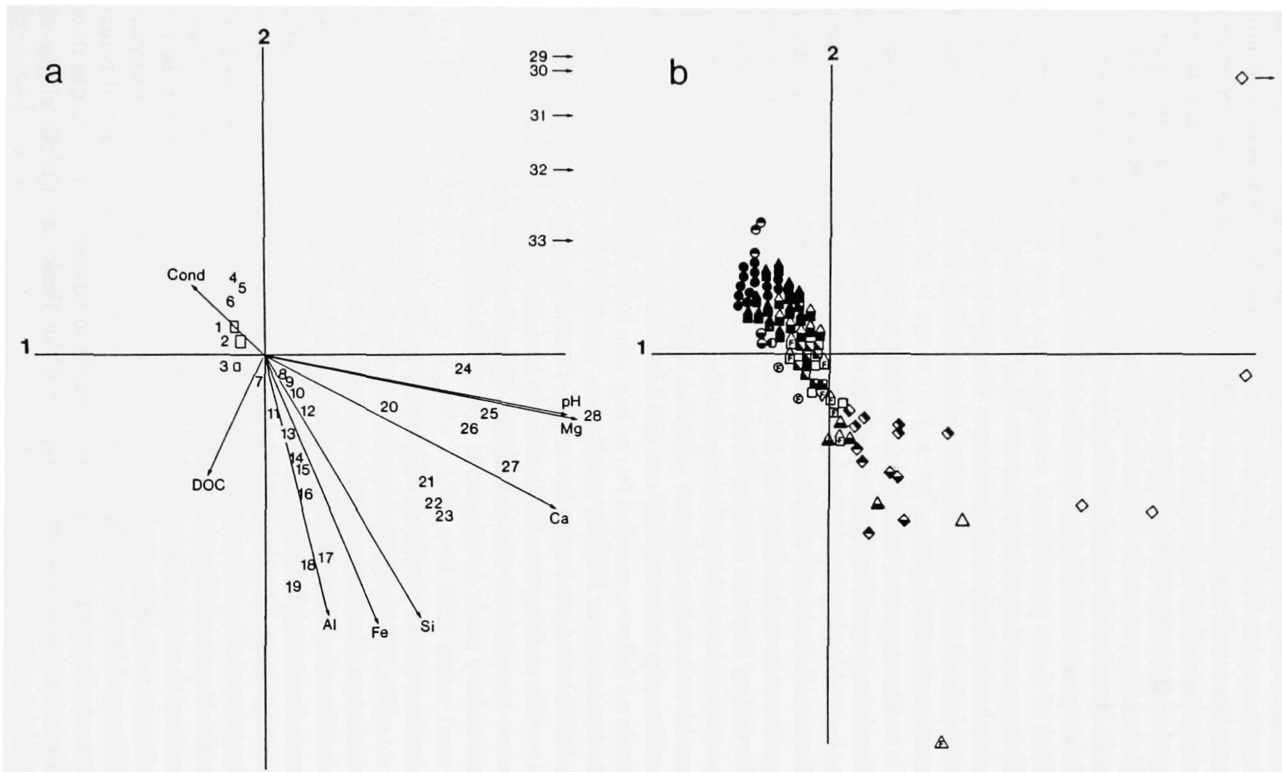


Figure 16. Canonical correspondence analysis (CCA) ordinations along the first two CCA axes. (a) CCA biplot; (b) vegetation sample scores. Complete caption was given on the facing page.

material, but usually somewhat greater proportions of herbaceous remains (largely *Eriophorum* spp. and other sedges) than the shrub heath types. Wooded fen and shrub thicket fen type (various subtypes and combinations: Table 8) peats contain much woody material (often well decomposed), and much less *Sphagnum* remains than any of the bog type peats. Fens mostly lacking woody plants (e.g., open fen [*Carex oligosperma/Sphagnum magellanicum*] and streamside meadow [*Carex* spp./*Calamogrostis canadensis*]) form peats with high proportions of fibrous remains of sedges. The first of these parenthetic examples is a poor fen with appreciable *Sphagnum* remains in its peat. The second example is more eutrophic and is subjected to stream floods. Its peat lacks appreciable amounts of *Sphagnum* and contains both grass and sedge remains and much silt/clay.

The degree of woodedness of past peatland ecosystems (wooded fen or bog, open-wooded fen or bog, and open fen or bog) would tend to be underestimated by sampling with a Davis peat sampler due to the small diameter of the sampler and its tendency in soft peats to push aside rather than cut large chunks of wood. Thus, for reconstructing degrees of ecosystem woodedness based on the ancient peats, more wood was required in the samples than was observed in modern (hand grab) peat samples. The degree of woodedness was arbitrarily determined from the five point (0,1,2,3,4) Troels-Smith scale as follows: wooded fen or bog was inferred from samples with 2–4 points (≡ or > 50%) wood, open-wooded fen or bog from 1 point (~25%) wood, and open fen or bog from 0 point or trace wood.

No probing was carried out in secondary pools, although these were common on the peatlands. Therefore, the manner in which secondary pools developed is not revealed by these data.

An example of peatland origin and development: Big Bog (Fig. 21)

The stratigraphic results from Big Bog (Appendix 2) have been chosen to illustrate our interpretational approach. At each depth, shorthand symbols for Troels-Smith (Aaby and Berglund 1986) peat or sediment types are given. The stratigraphic columns are specially arranged: starting on the left is the lowest altitude site (fen below bog slope). The column on the right of that represents the low part of the bog slope. Next are two columns from middle parts of the slope, and on the right is a column from the top of the bog. These relative elevational positions were determined from informal field observations and from overflights and aerial photos—with especial reference to linear patterns on the peatland surface that indicate flow directions and therefore slope. Unlike Perkins's (1985) study at

Smith Brook Deadwater, leveling surveys were not carried out. Hence, the tops of the stratigraphic columns (Appendix 2) could not be arranged according to altitude as in Figure 4. Our only recourse was to reference all the tops to the peatland surface. The stratigraphic columns for every bog (Appendix 2) are similarly arranged: most peripheral/lowest fen site on the left; increasingly higher bog sites toward the right (ending with back slope sites near upland, if any were sampled); and all referenced to the peatland surface. As for Big Bog (Fig. 21), the map positions of the stratigraphic sites can be seen on plan maps.

At Big Bog relevé site BB1, the bottom sediment is a gravel/sand/silt mixture with some humic material, possibly the predominantly mineral subsoil of a terrestrial community (but, see below). Immediately above that is a peat consisting largely of wood remains with some indistinguishable humic material and a minor amount of *Sphagnum* remains. This represents a wooded fen. Three feet above that the peat consists of herbaceous plant matter, largely the fibrous remains of sedges, with some indistinguishable humic matter and a minor amount of *Sphagnum* remains, most probably representing an open sedge fen. Finally, the near-surface peat consists largely of *Sphagnum* remains (suggesting an oligotrophication) with a component of herbaceous matter (sedge). The present vegetation is an open fen (*Carex oligosperma/Sphagnum magellanicum*) mapped as cover type S/ML (Fig. 21).

The bottom substrate and earliest peat at BB1 suggest that at this site peatland originated by primary mire formation. This mode of origin refers to peatland starting directly on moist mineral substrate, with no intervening lacustrine or terrestrial (non-wetland) ecosystem stage (Sjörs 1983).

Peatland origins at relevés BB5, BB4, and BB2 differ from BB1. Basal mineral materials consist of glaciolacustrine clay-silt at BB5 and gravel topped by glaciolacustrine clay-silt at BB2. Organic lake sediments were found at the next higher levels sampled at these two sites and at the deepest level that was reached at BB4. These sediments consist of fine organic detritus with humic matter and diatom remains. The near-absence of clastic mineral matter suggests that wetlands already surrounded the lake, intercepting and filtering runoff from the uplands. This type of organic lake sediment (dy) is formed today in brown (humic) water lakes (= dystrophic lakes) surrounded by peatlands. The next higher sample at the three sites represents fen with some woody plants—specifically open wooded fen at BB5 and BB2. The three sites underwent terrestrialization (wetland replacing open water), the second of three modes of peatland origin (Sjörs 1983). (The third mode, paludification, is describe later.)

Site BB5, at the base of the bog slope, remains a fen today (although within an area mapped as forested bog), but BB2 and BB4 up the bog slope have been bog areas for some time, as inferred from the abundance of *Sphagnum* remains and scarcity of sedge remains at mid to upper peat depths.

Big Bog site BB3, now near the top of the bog slope, started on gravel as an open wooded fen by primary mire formation. This site, like BB2 and BB4, has been a bog for an appreciable length of time (as inferred from the long stratigraphic interval dominated by *Sphagnum* remains), but no radiocarbon or other dating methods were used for determining the actual durations of these sequences.

Eccentric bog-complex origins in general in Maine

The same interpretational approach applied to Big Bog was applied to all 15 bog complexes. This approach yielded generalizations that are summarized in Figure 17. All but one (Nollesemic Stream) of the eccentric units are underlain largely by clay-silt mineral substrate, and at most of the bog areas that substrate is overlain by dy. Of the 91 sediment/peat sampling sites where basal mineral substrates were reached[10], the substrate consisted entirely of clay-silt in 62 cases. In an additional 11 cases a predominantly clay-silt deposit contained an admixture of sand and/or gravel.

The clay-silt material is glacial "rock flour" that was initially deposited in this region 12,000 to 13,000 ^{14}C years ago by glacial meltwater and/or as a component of glacial till (Davis and Jacobson 1985; Jacobson and Davis 1988). A major portion of the clay-silt would have been deposited directly in the basin or valley bottom now occupied by a peatland. In most cases, that deposition was in a lake or marine embayment. An additional portion would have been eroded and transported (in part, possibly as late as 10,000–12,000 ^{14}C yr B.P.) from upland slopes to the basins and valley bottoms, adding to the considerable depths of clay-silt that underlie many Maine peatlands (Davis and Hu in prep.).

At relatively low altitude in the mid- and southwestern part of the region of eccentric bogs in Maine, the clay-silts were initially deposited in marine (probably brackish) embayments that occupied what are now tributary valleys of the Penobscot River, but then were below sea level due to glacial isostatic depression of the landscape. In the Millinocket area, there is evidence of this marine incursion up to a present elevation of at least 370 ft (113 m) a.s.l. (Thompson and Borns 1985). That far inland in the region of

[10]In most of the remaining peat sampling sites (there was a total of 113 sites), organic lake sediment was not penetrated all the way to the mineral base due to a limited supply of extension rods. At the other remaining sites, a layer at 12 ft or deeper of large pieces of wood prevented (after multiple attempts) a penetration to [illegible]

eccentric bogs the marine incursion would have been short-lived, at most a few hundred years after glacial recession; isostatic rebound soon caused a drainage of the marine waters. On drained slopes the glaciomarine deposits were exposed to the atmosphere and mostly occupied by terrestrial communities; in many valley bottoms the marine waters were replaced by fresh water lakes. In these early lakes, deposition (and redeposition from within and outside the lakes) of predominantly clay-silt sediment would have continued until biological productivity was sufficient to produce organic sediments and to mostly stabilize terrestrial areas of erodible clay-silt.

The basins of the bog at Cold Stream (present peatland surface altitude ca. 145 ft or 44 m a.s.l.), Inman Bog (335 ft or 102 m), and possibly also Hatham Bog (375 ft or 114 m) were initially occupied by marine waters which were replaced by shallow lakes.

Elsewhere in the eccentric bog region, proglacial and near-glacial lakes rather than marine embayments were the initial depositories for the clay-silt. Rapid sedimentation of clay-silt, followed by accumulation of organic lake sediment shallowed the basins. The resultant gently sloping shallows were colonized by wetland plants—leading to further shallowing and peatland development by terrestrialization ("T" in Fig. 17).

Single large basins (with lakes) need not have been present at the outset of peatland development. Along irregular valley slopes, multiple small basins of accumulation in close proximity to each other may have been present, as proposed earlier (Figs. 1 & 4–7). For example, at least three aquatic basins separated by emergent areas (islands, peninsulas, and/or isthmuses) were present along the valley slope at Smith Brook Deadwater (Perkins 1985; Fig. 4). While the first peats in those basins are underlain by dy, the first peats on the emergent areas are underlain by non-lacustrine substrates. Our data from other eccentric bogs are inadequate to (1) test single or multiple basin hypotheses, and (2) if multiple basins were initially present, to determine the manner and direction(s) of spread of peat between the basins during the preliminary stages of eccentric bog development. Clearly, much remains to be learned about the origins of eccentric bogs in Maine.

At clay-silt filled areas with flat or very gently sloping clay-silt surfaces where permanent standing water was absent but the surfaces remained moist due to favorable hydrological conditions and the poor permeability of the clay-silt, wetlands could develop directly by primary mire formation ("M" in Fig. 17). Initially, these wetlands may have been non-peaty marshlands. "Primary peat" (see earlier, background section) is absent from these sites. Primary mire formation also occurred on moist sand and gravel substrates.

Figure 17. Summary developmental sequences for Maine's eccentric bog complexes, based on peat stratigraphic studies at 15 complexes. Of the 113 probe sites, data from 107 were sufficient for inclusion here. Thicknesses of arrows are proportional to the relative frequencies of transitions. Numbers for the three mineral substrate types (bottom) are numbers of probe sites where the substrates were found to directly underlie bottom peats or organic lake sediments. Due to wood obstructions and other difficulties, at only 91 of the 107 sites was mineral substrate reached. "Lake" means primary lake (not secondary pool). Numbers of the six wetland ecosystem types indicate present end point of hydrosere (present ecosystem type at probing site). Thus, 37 of the 107 sites are fens (only one of which had reverted from bog). T = terrestrialization; M = primary mire formation; P = paludification (provisional; see text). No probing was carried out in secondary pools, although these were present on the peatlands. For past ecosystems, the three fen and three bog types were arbitrarily determined from the five point (0,1,2,3,4) Troels-Smith scale: wooded fen or bog was inferred from samples with 2-4 points (=~ or > 50%) wood, open-wooded fen or bog from 1 point (~25%) wood, and open fen or bog from 0 point or trace wood. For other distinctions (e.g., fen versus bog) see text. In accordance with the reconnaissance nature of these stratigraphic studies, past ecosystem types are broadly categorized. These broad categories cannot be readily equated to specific modern vegetation types.

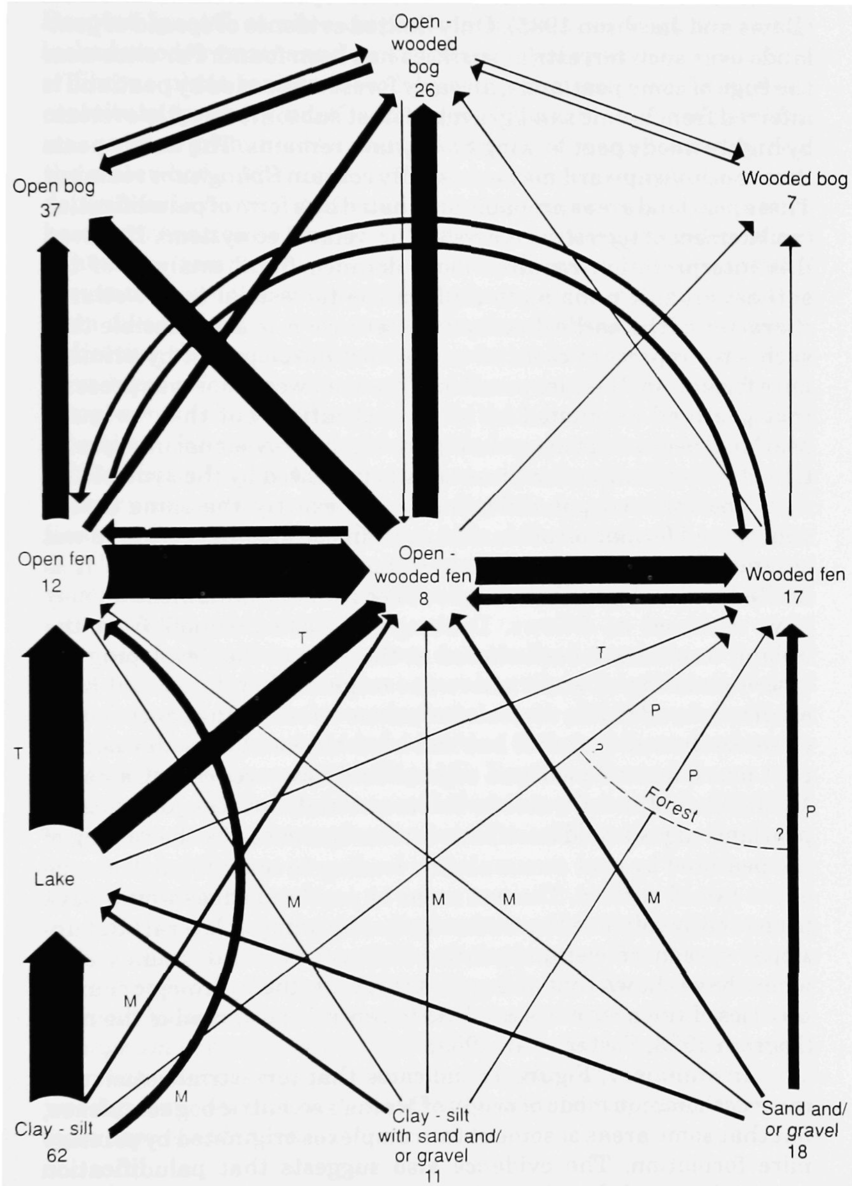


Figure 17. Summary developmental sequences for Maine's eccentric bog complexes. Complete caption was given on facing page.

Outside the basins, terrestrial ecosystems developed: at first tundra and after one to two millennia open woodland or forest (Davis and Jacobson 1985). Only limited evidence of spread of peatlands over such terrestrial surfaces has been found. For sites near the edge of some peatlands, an early forest succeeded by peatland is inferred from humic sand/gravels (forest subsoil?) directly overlain by highly woody peat lacking *Sphagnum* remains. The woody peats that continue upward may eventually contain *Sphagnum* remains. These peatland areas probably originated by a form of paludification (replacement of terrestrial ecosystem by wetland ecosystem). However, this interpretation requires more detailed floral analysis of the earliest organic remains to confirm the terrestrial (non-wetland) character of the earliest ecosystem because it is also possible that such sites represent cases of wooded fen development by primary mire formation. It is also possible, if a wave-swept zone was present, that peatland originated by terrestrialization, but that "primary peat" had been swept away. In Figure 17, the provisional interpretation of paludification for these sites is indicated by the symbol "P"

The inferred paludification is not exactly the same as the widespread formation of blanket peatland on sloping terrain in wet oceanic climates (e.g., western Ireland) because in Maine it is limited to the slopes at the edges of bogs.[11] This paludification may have occurred as follows. Drainage of surface runoff from the upland would have been slowed at the edge of the developing fen where puddling of water above the original shoreline could have occurred. In addition, diversion of minor streams (that once flowed closer to the valley center but had been blocked by the developing peat mass) around peatland edges would have occurred (Cameron 1975). The influx of water to the terrestrial surfaces just outside peatland edges would have been further increased by the raising of the peatland by peat accumulation leading to centrifugal drainage of the raised surface. The wet areas at peatland edges would have been readily colonized by wetland plants leading to lateral (and upslope) spread of wetland/peatland. Developmental studies elsewhere have shown that as bog peat thickens, the hydrologic characteristics of the peat mass can lead to centrifugal spread of the mire (Ingram 1983; Foster et al. 1988).

In summary, Figure 17 indicates that terrestrialization was the most common mode of origin of Maine's eccentric bog complexes, but that some areas of some of the complexes originated by primary mire formation. The evidence also suggests that paludification occurred around the edges of some of the complexes (see stratigraphic sequences in Appendix 2).

[11]Maine's maritime-slope and subalpine/alpine-slope peatlands (Table 2) are similar to blanket bogs, but in Maine such peatlands are very small, few in number, and restricted in distribution (Davis 1

Early peatland stages

In all cases, the earliest peatland stages were fens (Fig. 17). Deepest "peats" at sites originating from lakes most frequently lacked woody remains and consisted largely of dy with an admixture of fibrous plant matter including sedge remains. Together these constitute "primary peat" and suggest that the earliest peatland was an open graminoid fen that had invaded the shallowest parts of the water body. The abundance of dy in these samples indicates deposition in a water body and that the plant remains must have been transported to the relatively deep water site of deposition (where the sample was taken). At a small minority of sites, small amounts of wood, sometimes in chunks too large to have originated from dwarf shrubs, were present in the dy/fibrous peat mixture, indicating that at those basins the peatlands at the shallows may have been at least partly wooded. After a variable interval, the dy component of the peat disappears. By that time a fen had developed directly at the sample site, and "secondary peat" was being formed *in situ*. Usually, *Sphagnum* remains were absent or sparse in the primary peats and earliest secondary peats, suggesting that conditions for *Sphagnum* growth were poor. After a period of *in situ* fen development, however, *Sphagnum* remains first appear or increase in abundance, suggesting an acidification/oligotrophication of the fen (Gorham et al. 1987).

Most of the open fen sites eventually became open-wooded fens, and many of these became more heavily wooded fens (inferred from superposed densely woody peats). Some of these reverted back to a less wooded or unwooded condition (inferred from decrease or absence of woody remains) (Fig. 17). Degrees of woodedness may have frequently changed at specific locations, but sample intervals were too coarse and samples too small to confirm this.

Later peatland stages

Many of the investigated relevé sites and observation points have remained in a fen condition to the present day. Many others have developed a bog condition (Fig. 17). The latter have upper "tertiary peats" with minimal fibrous/sedge content and maximal *Sphagnum* content (with or without wood). About half the present open bog sites developed from open fens, the other half from open-wooded fens. Most of the present open-wooded bog sites developed from open-wooded fens.

Development of surface patterns

There is no direct information on the chronology or manner of development of the parallel surface patterns of Maine's eccentric bogs. Hypotheses developed in other geographic areas are referred to in the "background" section earlier in this report. It has been pointed out that the parallel arrangements of ridges and troughs on peatlands always develop perpendicular to the slope and direction of water flow. Eccentric bogs have eccentric slopes. Accordingly, the arrangement of pattern on them is eccentric (approximate ladder to approximate fan arrangements) rather than concentric.

Summary of origins and development of Maine's eccentric bog complexes

At a large majority of sites, peats are underlain by organic lake sediments which, in turn, are underlain by clay-silts. At these sites, fens (mostly open and open-wooded types) originated by terrestrialization. At a minority of sites organic lake sediments are absent, and bottom peats lay directly on clay-silts and/or sands and gravels. At most of these sites, the fens (mostly open and open-wooded types) developed directly on mineral substrates by primary mire formation, with no intervening lake stage. At a smaller number of the sites lacking a lake stage, and restricted to peatland edges, wooded fens appear to have formed by lateral spread of the peatland and paludification of originally terrestrial ecosystems.

The bog (ombrotrophic) units of Maine's eccentric bog complexes developed from open and semi-wooded fens by thickening of peat. Today, the complexes continue to contain large areas that have not developed beyond a fen stage.

Comparison to bog development elsewhere in North America

Tallis (1983) summarized from the literature 36 peat sequences, 12 each from New England, the Great Lakes states, and the Pacific Coast (Fig. 18). Terrestrialization was the most frequent mode of origin, as at our sites in Maine, but "paludification" was also common. The main terrestrialization sequences were: lake mud to "sedimentary peat" (lake sediment with detritus from wetland plants, i.e., primary peat) or to sedge peat (from open fen), and sedimentary peat to sedge peat. Sedge peat was mainly followed by "forest peat" (from wooded and open-wooded fen or bog) and forest peat by "*Sphagnum* peat" (open bog). This overall sequence is similar to the main sequence at our eccentric bogs.

Tallis (1983:323) claimed that sedge peat is "typically produced by a floating raft of vegetation," but a floating condition was not inferred by most of the original authors whose sections contained bottom zones of sedge peat. One of the authors (Osvald 1935) did infer that sedge peat was formed as a floating raft during the terrestrialization phase at a small, deep basin.

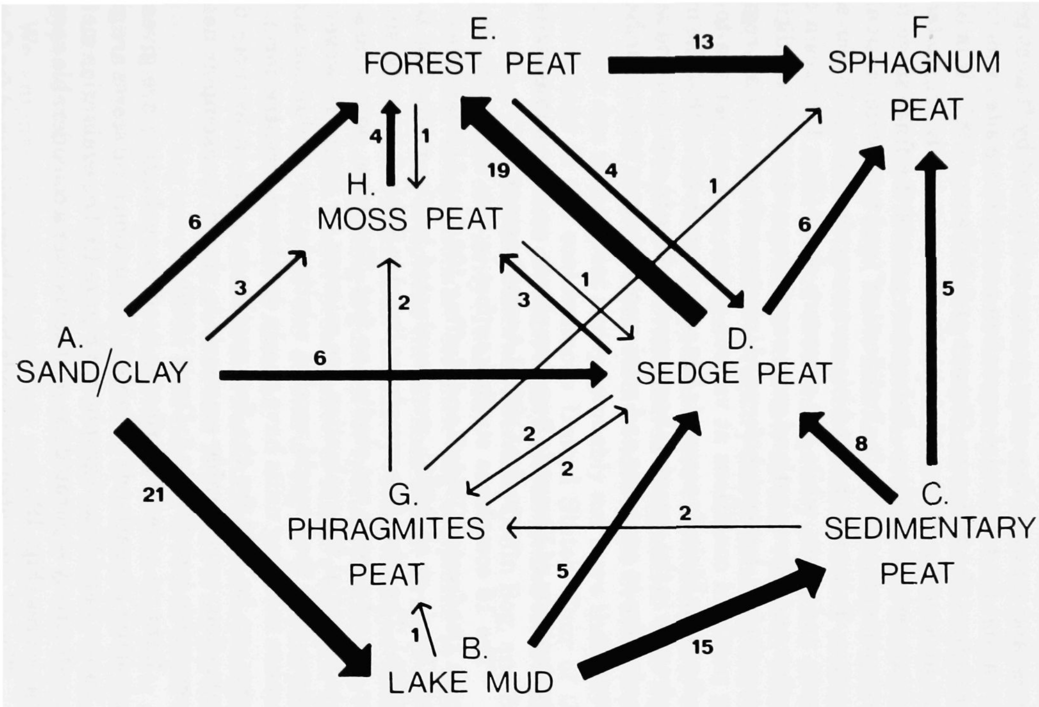


Figure 18. Stratigraphic sequences in sediments and peats from North American bogs, from Tallis (1983:324): "The arrows connect pairs of superposed strata in published profile descriptions; the number against each arrow gives the number of recorded instances of that particular transition." Reprinted, with permission, from Tallis (1983:324).

Tallis did not distinguish between paludification and primary mire formation as we have done (following Sjörs 1983) for Maine's eccentric bogs, and, given the limited evidence for strict paludification at most of the sites he reviewed, it is possible that primary mire formation was also a common mode of origin. At his "paludification" sites, sedge peat and "forest peat" are about equally frequent as first types, and many of the sedge peats are followed by "forest peat" Given that the terrestrial vegetation around those sites was forest throughout the Holocene (Bryant and Holloway 1985), it is likely that at least the sites with initial sedge peat really originated by primary mire formation. *Sphagnum* peat is the final stage for a large percentage of the "palludification" (and terrestrialization) sequences. Tallis constructed his summary chart (Fig. 18) for sediments and peats, while our summary chart (Fig. 17) goes a step further and infers peatland gross vegetation and trophic conditions. Nevertheless, by straightforward inferences from his chart regarding peatland conditions at various stages and comparison to our findings for Maine's eccentric bog complexes, we find that the main hydrosere in the eccentric bogs, namely, lake to open fen and semi-wooded fen to open bog and semi-wooded bog, is typical for North America.

Evaluations of Eccentric Bog Complexes, and Recommendations to the Critical Areas Program

The 15 complexes studied on foot in this study, plus Smith Brook Deadwater (Widoff and Ruffing 1984) and Greenville Junction (Davis et al. 1983), were evaluated by the method of Davis (1989b). The other five complexes listed in Table 3, namely, sites a, b, c, e, and g, were not studied on foot. Therefore, some classes of data essential for evaluation are missing for them. However, we believe that they would receive relatively low evaluation scores because their bog units have poorly developed eccentric form. The same can be said for the five peatlands listed in footnote 6. In evaluation, considerable emphasis is placed on exemplariness of geomorphic type (Table 5; Davis 1989b).

Data on several attributes used in evaluation are given for each of the 17 peatlands in Table 7. Evaluation total scores are given in Tables 7 and 15 and graphed in Figure 19. The evaluation method has effectively separated the peatlands over a considerable range of total scores (Fig. 19).

The 17 evaluated peatlands have been prioritized for Critical Area designation (Table 15), largely according to their evaluation total scores, but also according to additional considerations. For peatlands whose priority placement in Table 15 is out of scoring order, explanations can be found in their descriptions in the next section of this report. The boundary score between "recommended" and "not now recommended" for Critical Area designation was arbitrarily placed at 35. The small difference in score between the recommended Hatham Bog (35.3) and the not now recommended Peatland at Flinn Pond (34.7) does not reveal the major relevant difference between these sites. This difference is briefly explained in Table 15 (footnote b) and more fully in the site descriptions.

The evaluation total scores have comparative value within the context of Maine's eccentric bog complexes, but they do not relate these peatlands to the several other peatland types in the state. The latter comparisons will be carried out after studies of the other types have been published (e.g., Davis and Anderson in prep. a and b). However, given the rarity and restricted distribution of eccentric bogs in North America and their infrequency elsewhere in the world, it would be imprudent to await further research before taking action toward Critical Area registry and protection of Maine's best examples of eccentric bogs.

Ten of the 17 evaluated peatlands are recommended to the Critical Areas Program for Critical Area designation. This high proportion (10/17) of study sites recommended to the Critical Areas Program is due to the great rarity (probably not more than 35) of eccentric bogs in the conterminous United States. Four of the eccentric bog complexes are most highly recommended for Critical Area status: Cold Stream, Macwahoc Stream, Coffin Bog, and Big Bog, in that order of priority (Table 15).

Informal comparisons of eccentric bog complexes to other types of inland bog complexes (in our data set) in terms of flora, vegetation, and environmental chemistry reveal no major differences. The most compelling argument for special consideration for Critical Area status and/or preservation of Maine's eccentric bog complexes is the rarity of the eccentric bog as a geomorphic/hydrologic landform in North America.

It should also be pointed out that transitional geomorphologies between bog types (Table 2) are common. The choice of the particular 15 eccentric bog complexes for field study in 1987 was based on minimal ambiguity regarding classification of their bog units as eccentric. Some sites, for example, sites a, b, c, e, and g in Table 3 (and those in footnote 6), appeared to be more transitional to other bog types and therefore were not examined further in this study.

We emphasize that eccentric bog units are part of larger peatland complexes, and these complexes are, with the exception of Inman Bog complex, part of multiple-unit peatlands (Table 7). Designated peatland Critical Areas should certainly include entire complexes, as it is likely that major disturbance (particularly if hydrology is altered) of any part of a complex will affect other parts. Furthermore, several of the eccentric bog complexes are part of multiple-unit peatlands containing units of differing geomorphic/hydrologic types that are also of interest as Critical Areas (see peatland descriptions). In such cases, it is desirable to designate as Critical Areas entire multiple-unit peatlands. Peatland areas mapped and evaluated for this report do not always include the entire areas that should be considered for Critical Area designation. That limitation is indicated, when relevant, in the peatland description.

Table 15. Priorities for Critical Area designation, and evaluation total scores for 17 eccentric bog complexes in Maine. The score based on species diversity index (D_e) is given in parentheses when it differs from the score based on number of species. The bogs are grouped in three priority classes. See text including peatland descriptions for explanations of prioritization.

Priority	Peatland	Score	Priority class
1	Cold Stream	63.0	Highly recommended
2	Macwahoc Stream	55.9[a] (58.9[a])	Highly recommended
3	Coffin Bog	49.1	Highly recommended
4	Big Bog	49.5[a]	Highly recommended
5	Wadleigh Bog	38.8 (36.8)	Recommended
6	Smith Brook Dwtr	43.9 (41.9)	Recommended
7	Lambert Lake	40.6	Recommended
8	Stetson Mountain	43.2	Recommended
9	Elevenmile Lake	41.3 (35.3)	Recommended
10	Hatham Bog	35.3[b] (37.3[b])	Recommended
11	Flinn Pond	34.7	Not now recommended
12	Crossuntic Stream	34.0 (32.0)	Not now recommended
13	Lindsey Brook	31.9 (29.9)	Not now recommended
14	Nollesemic Stream	27.9	Not now recommended
15	Vanceboro RR	24.1[a]	Not now recommended
16	Greenville Jctn	25.5 (24.5)	Not now recommended
17	Inman Bog	18.0	Not now recommended

[a]The total scores for these multiple-unit peatlands would be higher if the evaluation included the units that are outside the areas mapped for this study. See text for explanation.

[b]A type 6b bog unit at Hatham is exceptionally exemplary. When that unit is used for exemplariness of peatland type, the evaluation total score is 51.3 (or 53.3 when D_e is used; see Table 7).

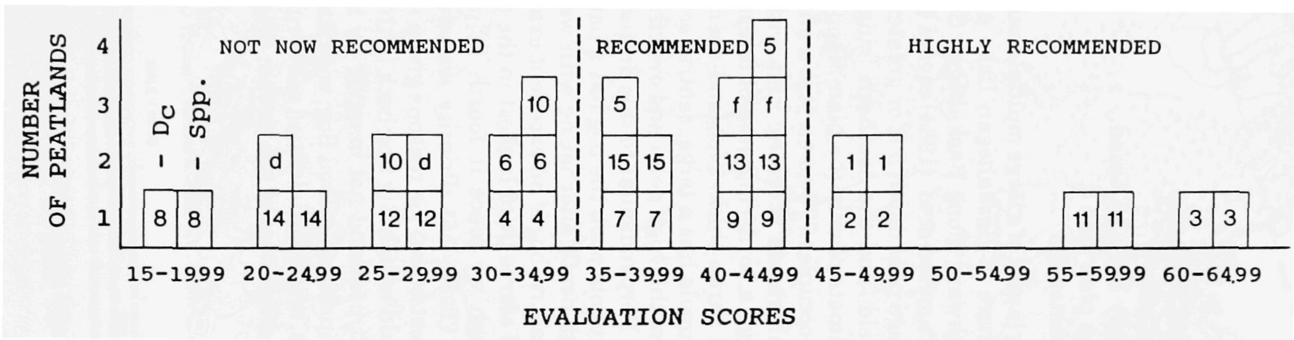


Figure 19. Distribution of evaluation scores of eccentric bog complexes. Peatland numbers and letters are indicated on histograms. See Table 7 to match numbers and letters to peatland names. For each score interval, the first histogram is for scores based on diversity index (D_c), the second on number of species (Table 7). The distribution is divided into three priority classes (see Table 15 and text).

Description and Map, Evaluation, and Recommendation as Critical Area of 15 Eccentric Bog Complexes

Big Bog

Kosuth (T7R2) Township
Washington County
USGS Scraggly Lake 15' Quad.
~776 acres on plan map
Highly recommended

Big Bog is part of a large multiple-unit peatland starting at the southwest shore of Baskahegan Lake and extending ca. 4 miles roughly southward along Baskahegan Stream (Fig. 20). The area mapped by Cameron et al. (1984) covers 490 acres and includes the area of average peat depth 5 ft or greater at Big Bog, Caribou Bog T7R2/Topsfield, and the southern fringes of Crabtree Bog. The digitizer estimate of only the plan-mapped Big Bog (Fig. 21) indicates that it occupies 776 acres. It is a mire complex consisting of a south-central, raised eccentric unit with a cupola at the south-southeast end, a bordering area of forested bog, and surrounding unpatterned shrub thicket fen and open-wooded and wooded fen areas. The cupola has a large, central secondary pool. Most of the drainage from this high point and over the eccentric bog is roughly to the north. Perpendicular to this drainage, and north and northwest of the cupola pool, the bog has a pattern of ridges covered by wooded shrub heath alternating with wet troughs and pools (Fig. 21). This eccentric bog is an excellent example of its type in Maine; the peatland scores third highest in the evaluation of 17 eccentric bogs, although we place it fourth in priority for Critical Area designation (Table 15). Priority was switched with Coffin Bog (fourth highest score) for reasons given in the Coffin Bog description. We would switch Big Bog back to third priority if areas of the multiple-unit peatland not mapped for this study were included. These areas include Caribou Bog, with its vague concentric pattern lacking pools, and a well-defined esker running along the west side of the wooded fen west of the stream (Fig. 20).

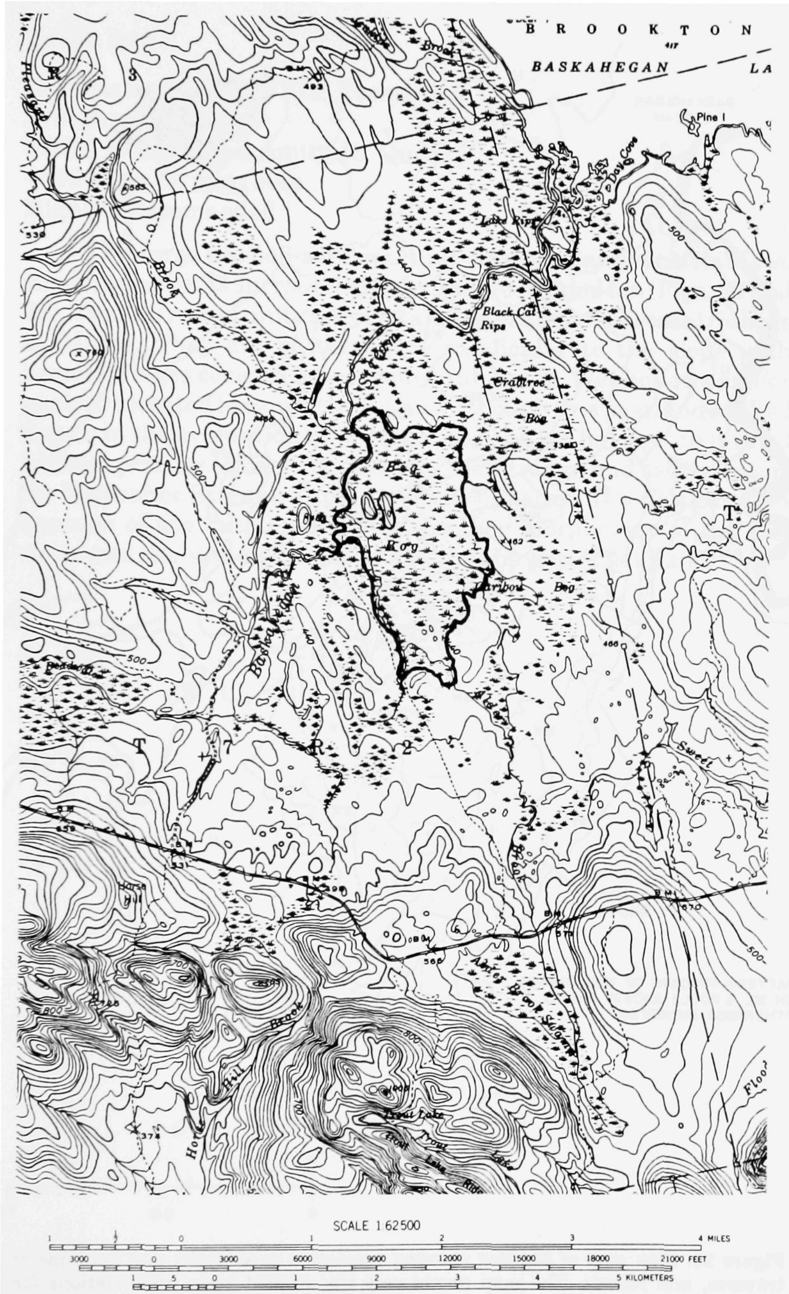


Figure 20. Big Bog. Study area outlined on USGS Scraggly Lake 15' quadrangle.

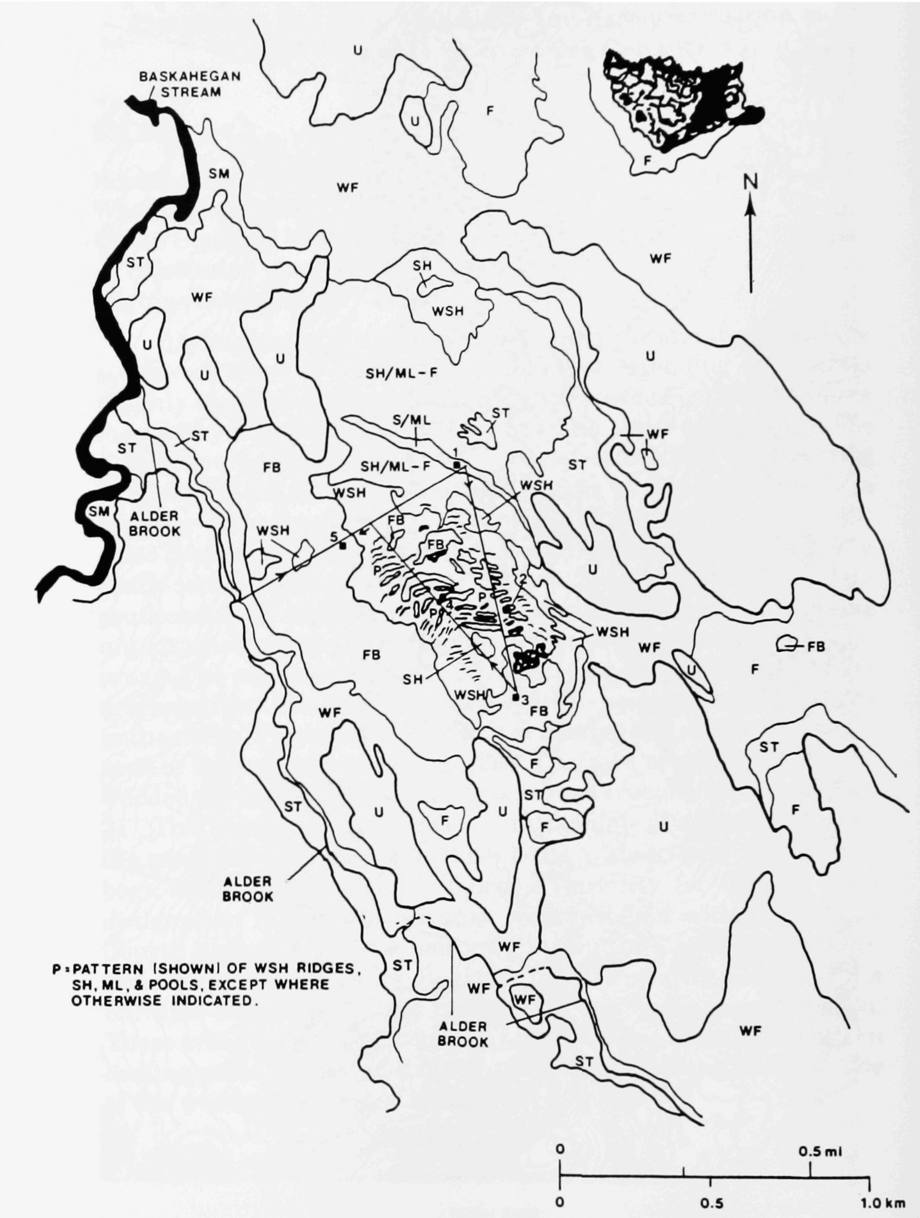


Figure 21. Plan map of Big Bog showing vegetation cover types and locations of traverse, and relevés. The map covers only the studied area. Abbreviations for vegetation cover types are defined in part II of Table 8. Small blackened squares indicate locations of numbered relevés. Numbered observation points were established only at certain peatlands; each such point is indicated by an x. Water areas are given in black.

Coffin Bog

Linneus and TAR2 WELS Townships
Aroostook County
USGS Houlton and Amity 15' Quads.
~556 acres on plan map
Highly recommended

This large (ca. 556-acre) multiple-unit peatland consists of two small raised units surrounded by extensive wooded fen (Figs. 22 and 23). The two raised units are outstanding examples of eccentric bogs in Maine. They are patterned perpendicular to the slope with parallel ridges covered by wooded shrub heath. Wet hollows and/or pools are located between the ridges. Although this peatland ranked fourth in the evaluation of 17 eccentric bogs, we have given it third highest priority (after first priority Cold Stream, and second priority Macwahoc Stream; Table 15) for designation as a Critical Area because of the outstanding eccentric bog morphology of the two units and the well-defined boundary of the entire peatland.

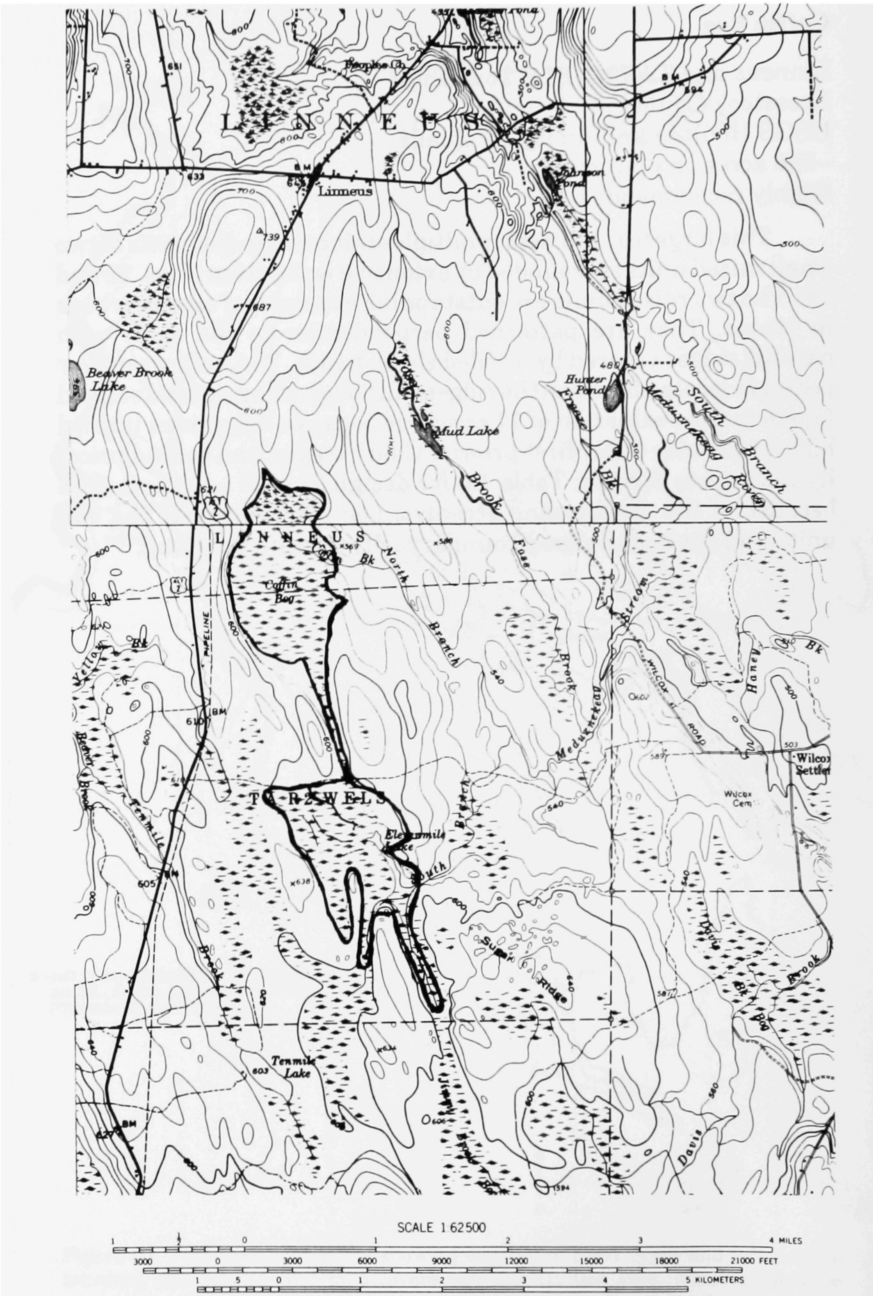


Figure 22. Coffin Bog. Study area outlined on USGS Houlton and Amity 15' quadrangles. Peatland at Elevenmile Lake is also shown.

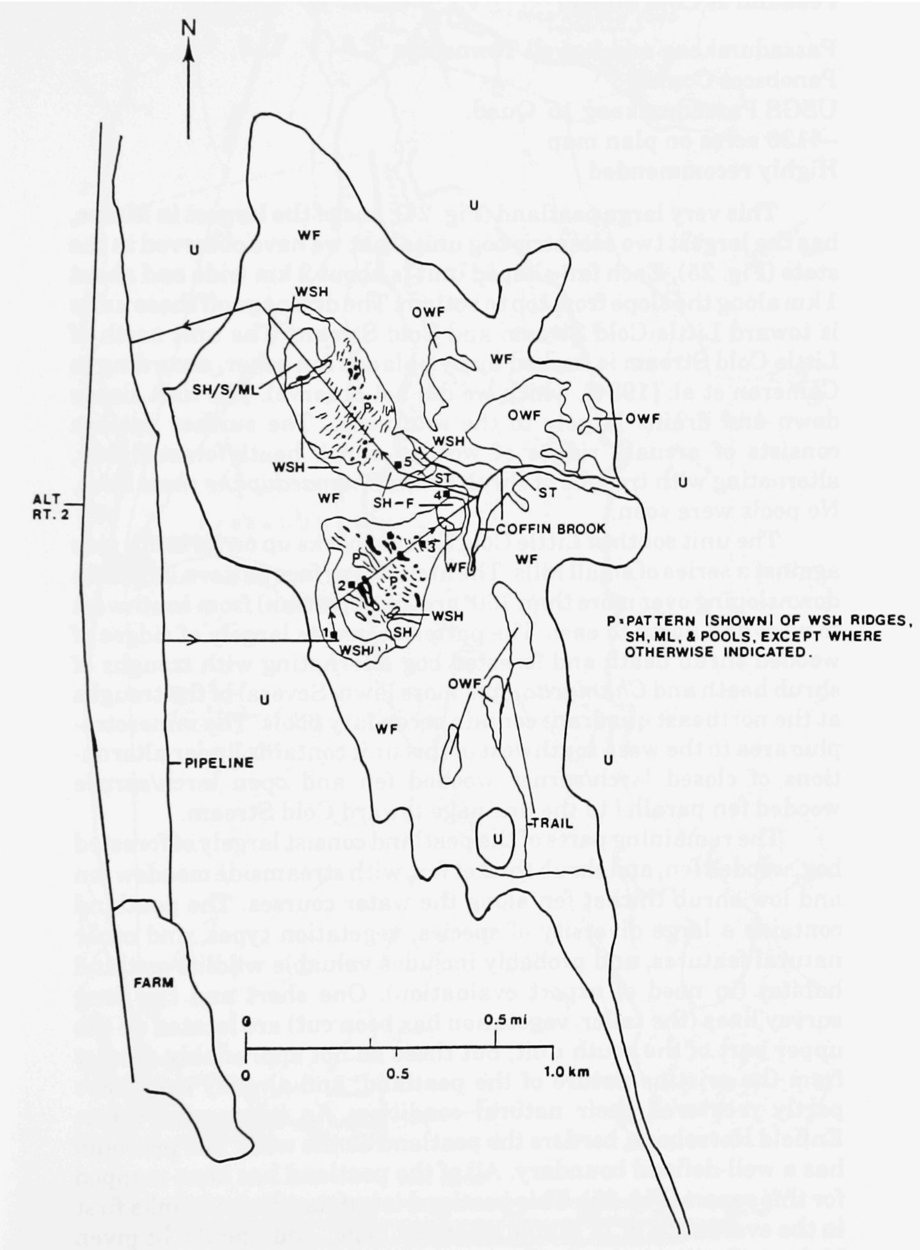


Figure 23. Plan map of Coffin Bog. See Figure 21 caption.

Peatland at Cold Stream

Passadumkeag and Lowell Townships
Penobscot County
USGS Passadumkeag 15' Quad.
~4130 acres on plan map
Highly recommended

This very large peatland (Fig. 24), one of the largest in Maine, has the largest two eccentric bog units that we have observed in the state (Fig. 25). Each fan-shaped unit is about 2 km wide and about 1 km along the slope from top to bottom. The drainage off these units is toward Little Cold Stream and Cold Stream. The unit north of Little Cold Stream is backed up by uplands (an esker, according to Cameron et al. [1984], which we did not observe). The unit slopes down and drains largely to the southwest. The surface pattern consists of arcuate ridges of wooded shrub heath/forested bog, alternating with troughs of shrub heath/*Chamaedaphne* moss lawn. No pools were seen.

The unit south of Little Cold Stream backs up on its south side against a series of small hills. The arcuate surface pattern indicates downsloping over more than 180° arc (like open fan) from southwest to west and north to east. The pattern consists largely of ridges of wooded shrub heath and forested bog alternating with troughs of shrub heath and *Chamaedaphne* moss lawn. Several of the troughs at the northeast quadrant contain secondary pools. The minerotrophic area to the west-southwest of this unit contains linear alternations of closed larch/spruce wooded fen and open larch/spruce wooded fen parallel to the drainage toward Cold Stream.

The remaining parts of the peatland consist largely of forested bog, wooded fen, and shrub thicket fen, with streamside meadow fen and low shrub thicket fen along the water courses. The peatland contains a large diversity of species, vegetation types, and other natural features, and probably includes valuable wildlife wetland habitat (in need of expert evaluation). One short and two long survey lines (the taller vegetation has been cut) are located on the upper part of the south unit, but these do not appreciably detract from the pristine nature of the peatland, and already they have partly recovered their natural condition. An impressive esker, Enfield Horseback, borders the peatland on the west. The peatland has a well-defined boundary. All of the peatland has been mapped for this report (Fig. 25). This peatland is outstanding; it ranks first in the evaluation of 17 Maine eccentric bogs, and should be given highest (first) priority for Critical Area designation (Table 15; see qualifications under description of Peatland at Macwahoc Stream).

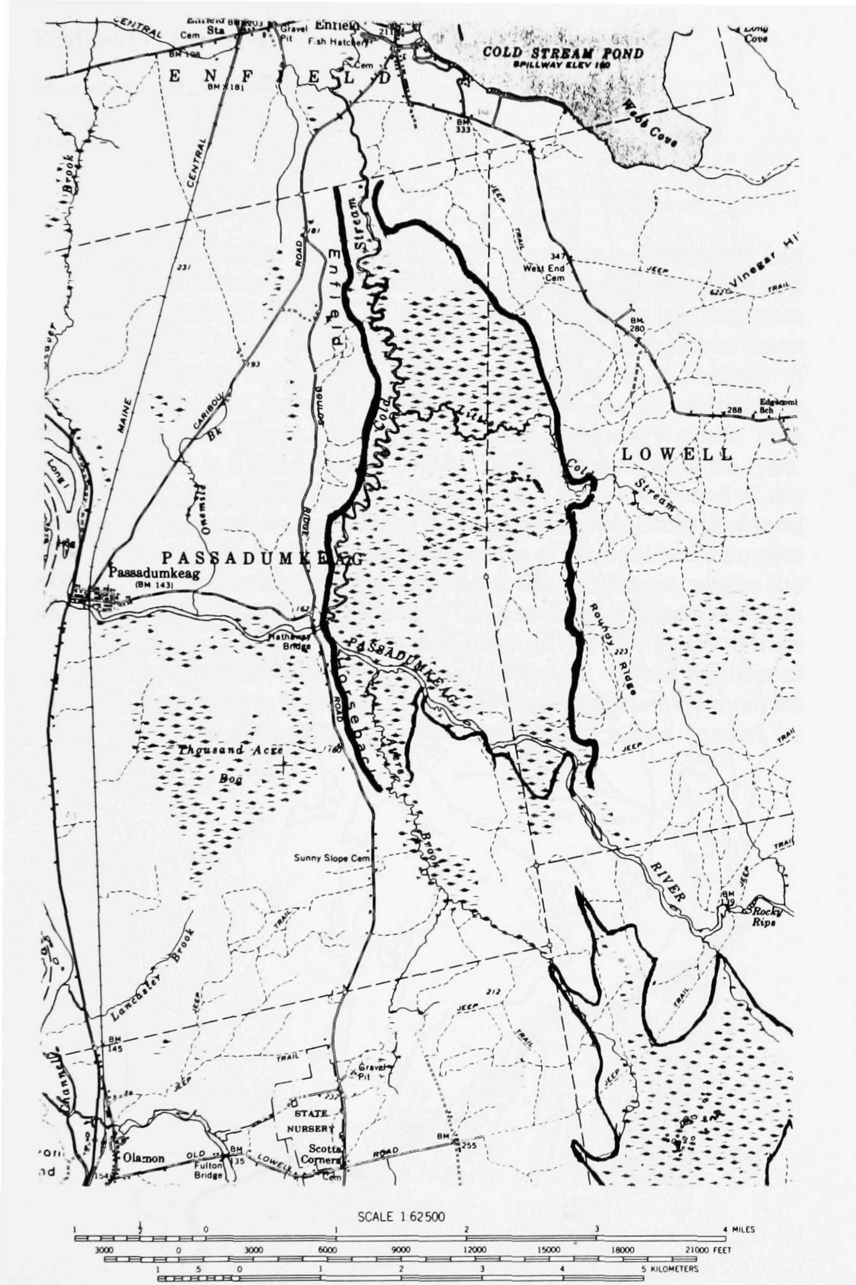


Figure 24. Peatland at Cold and Little Cold Streams. Study area outlined on USGS Passadumkeag 15' quadrangle. The bog at Rocky Rips is outlined on lower right (Davis and Anderson in prep. b).

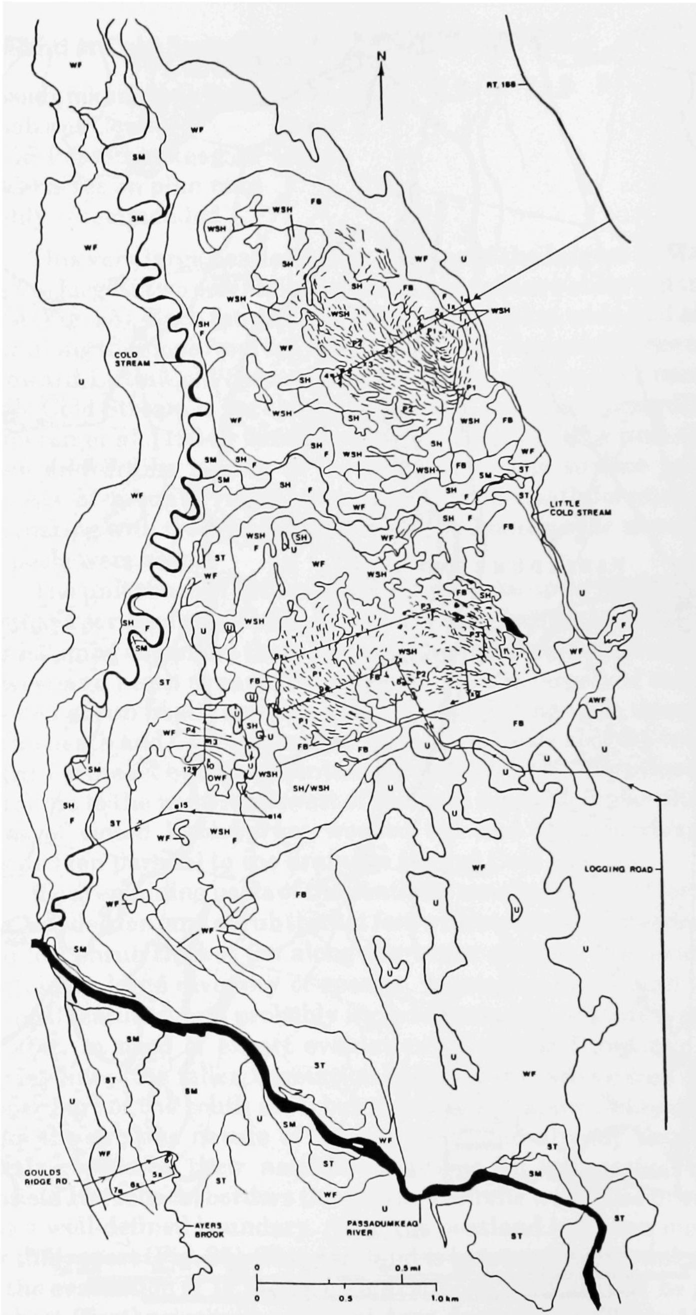


Figure 25. Plan map of Peatland at Cold Stream. See Figure 21 caption.

Peatland at Crossuntic Stream

Macwahoc and Kingman Townships
Aroostook and Penobscot Counties
USGS Wytopitlock 15' Quad.
~946 acres on plan map
Not now recommended

This large mire complex (Fig. 26) contains an eccentric bog unit (ca. 150 acres) nestled in, and draining into, the east side of a deadwater bend of Crossuntic Stream (Fig. 27). The top and east side of the unit abuts mineral upland in part. The unit slopes down toward the west-southwest. Crossing the slope is a pattern of parallel ridges of wooded shrub heath/shrub heath separating troughs of moss lawns, mud bottoms, and secondary pools. This eccentric unit is a good (Davis 1989b; Table 7) example of its type. On the west side of the stream, and ajacent to the south end of the deadwater, is a small transitional (*sensu* Davis et al. 1983) peatland unit. The vegetation of the peripheral parts of the peatland consists of extensive wooded fens (which extend to the northwest, and to the east beyond the plan-mapped area). The peatland ranked twelfth in the evaluation of 17 eccentric bogs and should not now be given high priority for Critical Area designation (Table 15) unless additional information comes to light (e.g., presence of rare species, of which we found none) or unless more highly prioritized areas cannot be designated.

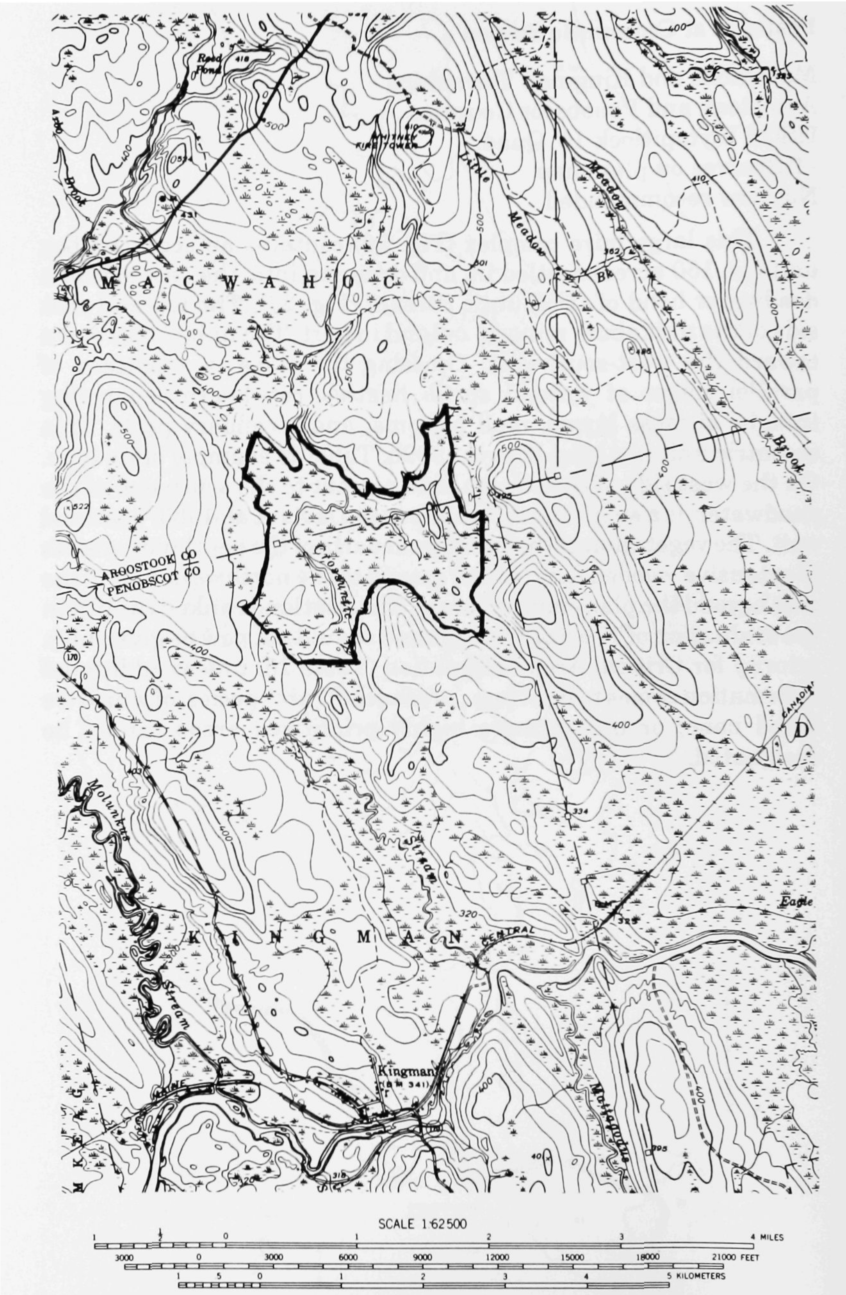


Figure 26. Peatland at Crossuntic Stream and County Line. Study area outlined on USGS Wytopitlock 15' quadrangle.

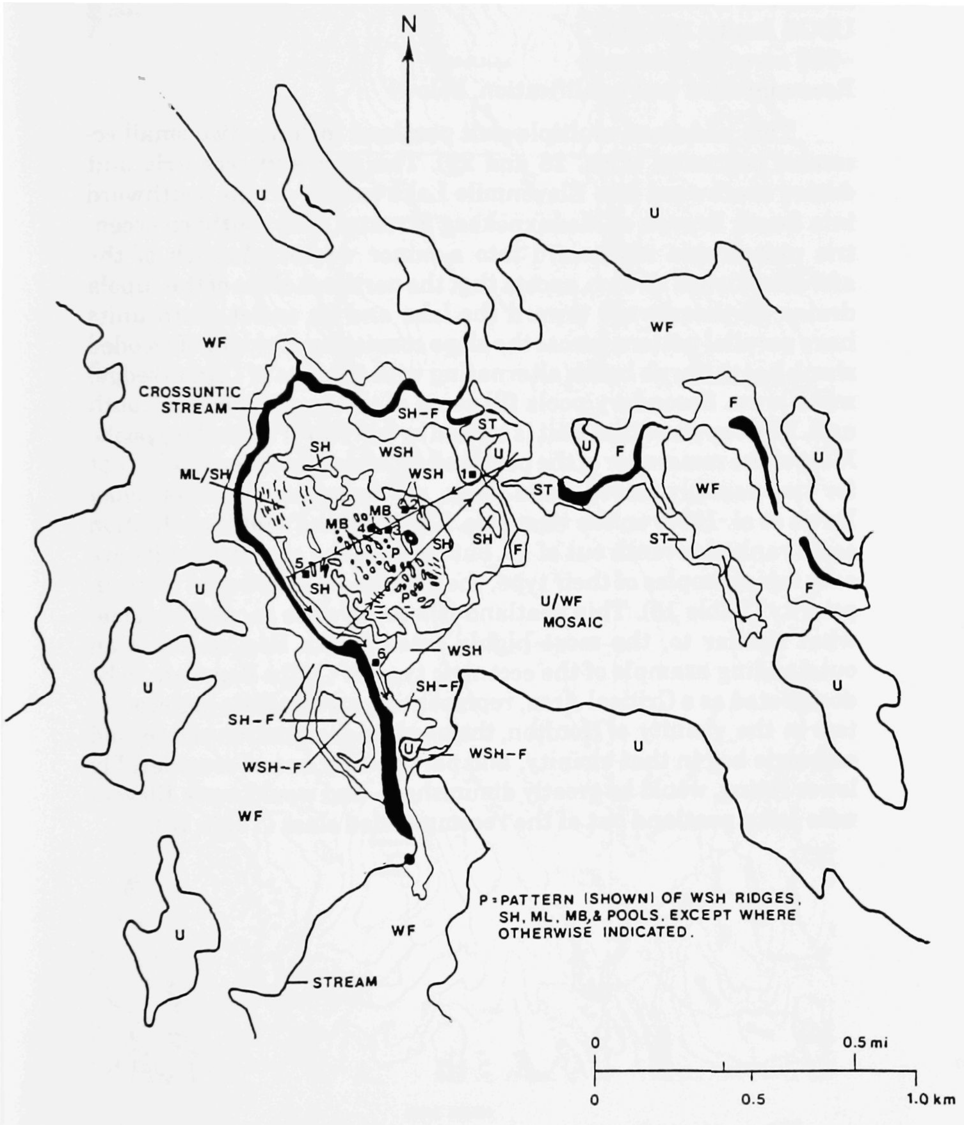


Figure 27. Plan map of Peatland at Crossuntic Stream. See Figure 21 caption.

Peatland at Elevenmile Lake

TAR2 WELS Township
Aroostook County
USGS Amity 15' Quad.
~395 acres on plan map
Recommended (see qualification, below)

This mid-sized multiple-unit peatland includes two small eccentric bog units (Figs. 28 and 29). The northern eccentric unit drains southward into Elevenmile Lake (which drains southward into South Branch of Meduxnekeag Stream). The southern eccentric unit drains southward into a minor western branch of the aforementioned stream, except that the northern slope of the cupola drains northeastward toward the lake and its outlet. Both units have parallel pattern across the slope consisting of ridges of wooded shrub heath/shrub heath alternating with troughs of *Carex* (sedge) moss lawn. Secondary pools fill some of the troughs at the south unit. The cupola of that unit is topped by a group of secondary pools. Most of the remainder of the peatland consists of wooded fen, except for two possibly raised units (bogs, or "transitional" units *sensu* Davis et al. 1983) on the west side. The peatland's total evaluation score ranked seventh out of 17, but because the eccentric units are only fair examples of their type, the peatland was lowered to ninth priority (Table 15). This peatland is located close to, and is somewhat similar to, the more highly rated Coffin Bog which is an outstanding example of the eccentric type. If Coffin Bog were to be designated as a Critical Area, representing an eccentric bog ecosystem in the vicinity of Houlton, the need for designation of a second eccentric bog in that vicinity, and particularly one of considerably lower rating, would be greatly diminished—and would move Elevenmile Lake peatland out of the recommended class (Table 15).

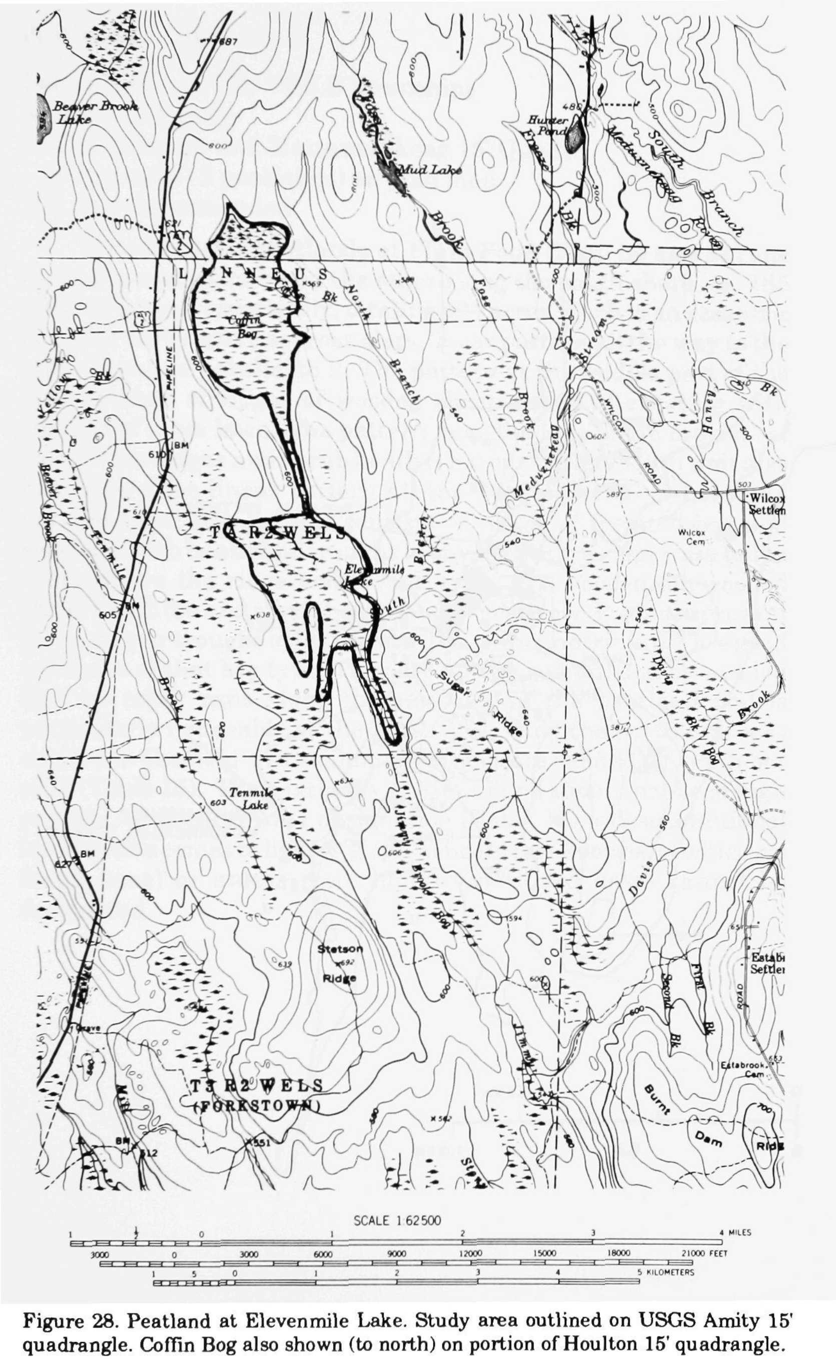


Figure 28. Peatland at Elevenmile Lake. Study area outlined on USGS Amity 15' quadrangle. Coffin Bog also shown (to north) on portion of Houlton 15' quadrangle.

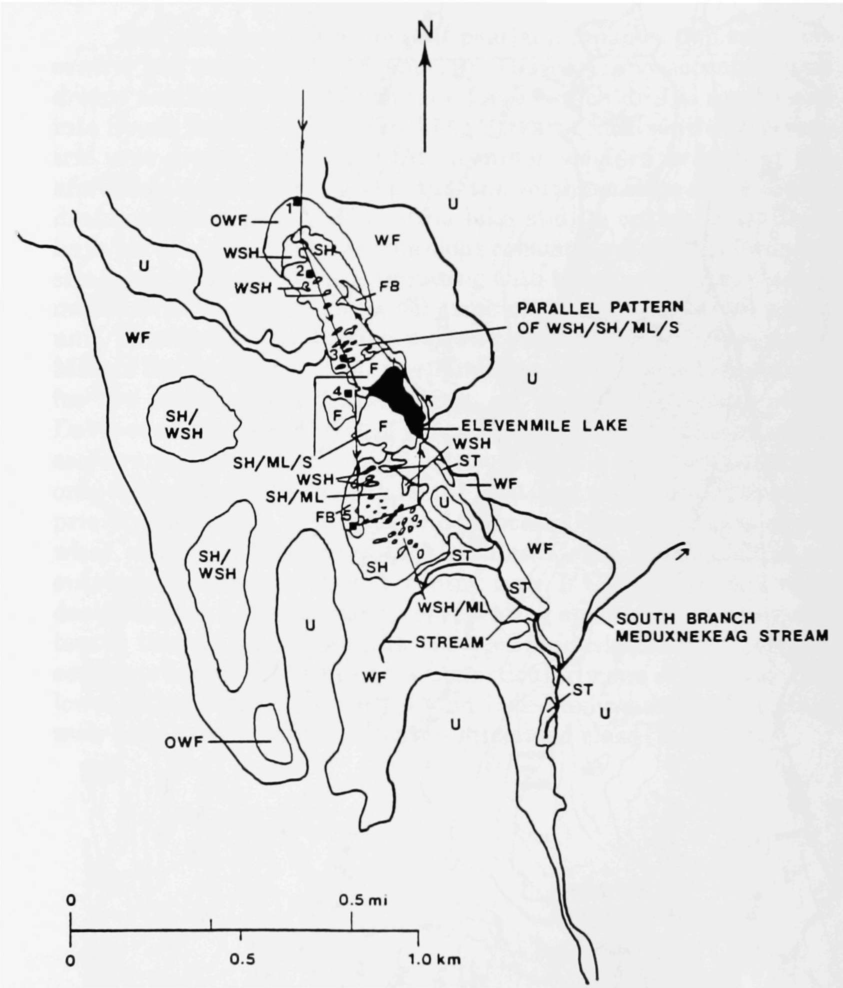


Figure 29. Plan map of Peatland at Elevenmile Lake. See Figure 21 caption.

Peatlands at Flinn Pond

Benedicta and T1R5 WELS Townships
Aroostook County
USGS Sherman and Mattawamkeag 15' Quads.
~494 acres (N+S peatlands) on plan map
Not now recommended

There are two peatlands at Flinn Pond (Figs. 30 and 31) one along the north shore and the other along the south shore, ca. 185 and 289 acres, respectively, totaling 494 acres. Each is an eccentric bog. The north unit has cross-slope linear pattern all the way to the lake shore and parallel to it. The pattern at the middle part of the unit consists of ridges of wooded shrub heath alternating with troughs of moss lawn. The pattern near the lake shore consists of wooded fen ridges and shrub heath fen troughs. The south unit also has cross-slope linear pattern all the way to the lake shore and parallel to it. The pattern consists of ridges of forested bog and wooded shrub heath and troughs of shrub heath, except close to the shore where the ridge and trough types are wooded fen/wooded shrub heath fen and shrub heath fen, respectively. Pools are present in the deeper troughs of both units. The two eccentric units are good examples of that bog type. They are mostly surrounded by wooded fen. An esker runs along the east side of the peatland and is particularly noticeable at the south unit. Only the north unit was studied in the field. It's evaluation total score ranked eleventh out of 17 (Table 15). The peatlands at Flinn Pond should not be of high priority for Critical Area designation (Table 15) unless additional information comes to light (e.g., presence of rare species, of which we found none) or unless more highly prioritized areas cannot be designated.

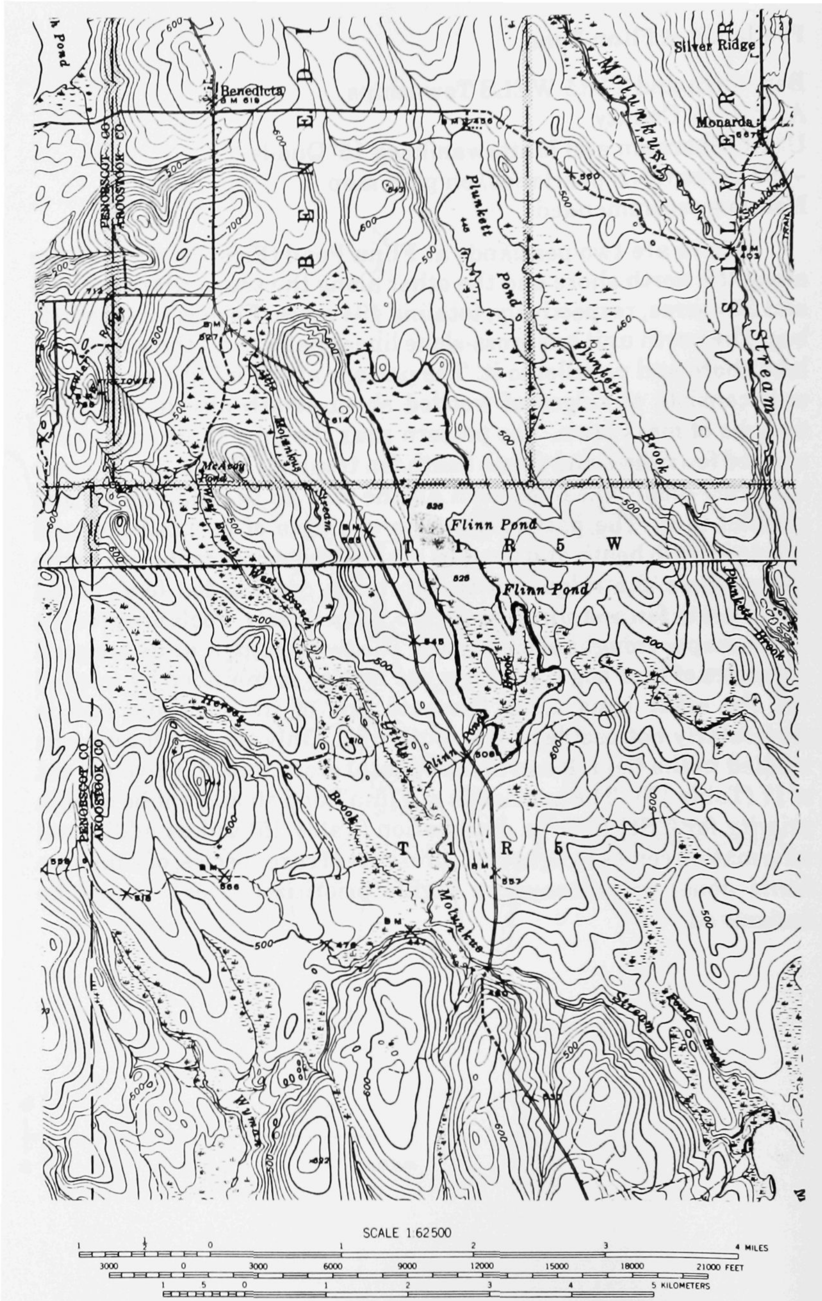


Figure 30. Peatlands N. and S. of Flinn Pond. Study area outlined on USGS Sherman and Mattawamkeag 15' quadrangles

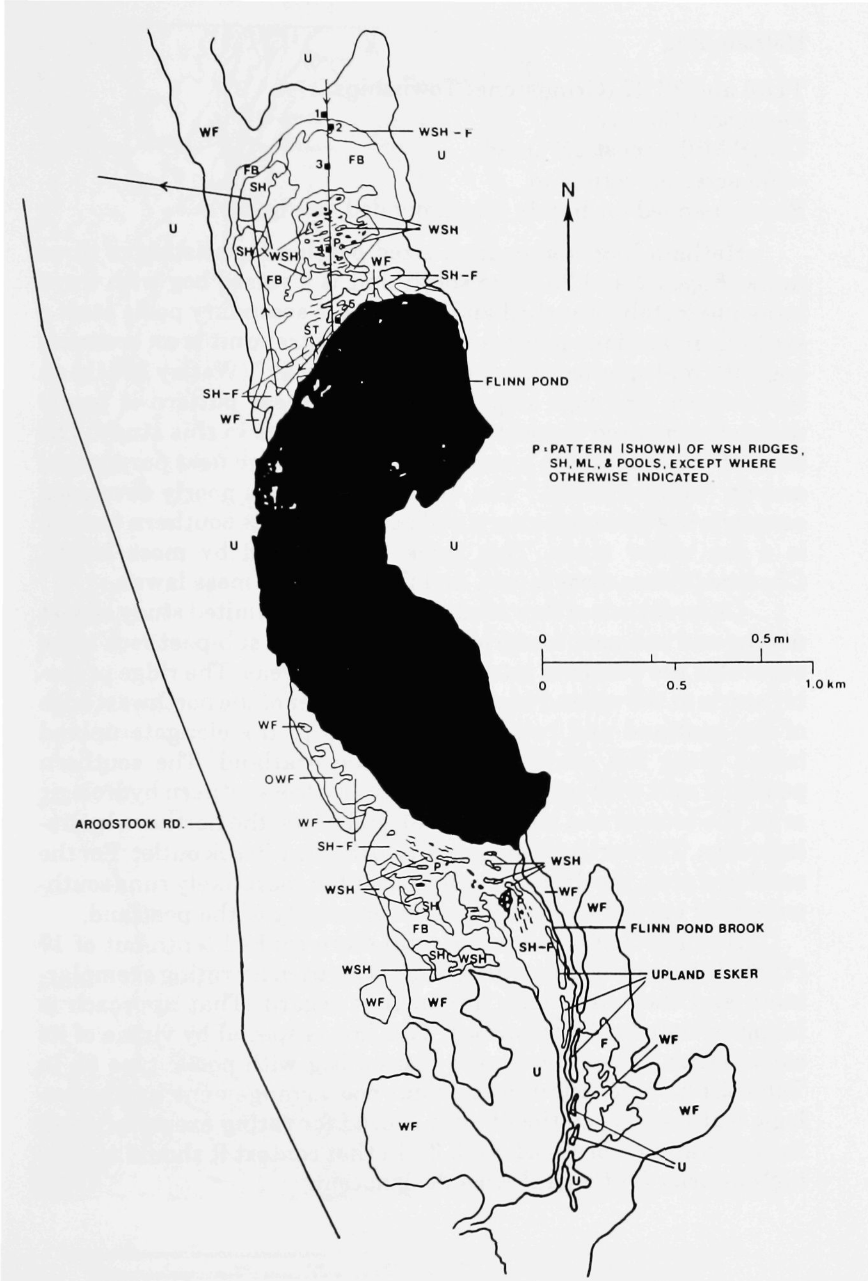


Figure 31. Plan map of Peatlands at Flinn Pond. See Figure 21 caption.

Hatham Bog

T1R6 and T1R7 (Grindstone) Townships
Penobscot County
USGS Millinocket 15' Quad.
~366 acres on map plan
Recommended (or highly recommended, see below)

Hatham Bog is a medium-sized peatland consisting of three units (Figs. 32 and 33). The south unit is a raised bog with three large intricately branched and/or multiple secondary pools atop: a striking and unique arrangement. The central unit is an eccentric bog with multiple secondary ponds and a "soak" (Worley 1981b) on its northern drainage slope. Cross-slope linear pattern is poorly defined, compared to most other eccentric bogs in this study. The head of this unit abuts a sub-peat rock ridge (see next paragraph) and an "upland island." The northern unit is a poorly developed eccentric bog lacking pattern and pools. Along its southern margin is a fen water track. This track is vegetated by moss lawns, *Chamaedaphne* moss lawns, and *Carex* (sedge) moss lawns.

Observations of flow of surface water and limited study of peat depths and sub-peat topography suggest that a sub-peat rock ridge separates the peatland into two hydrologic areas. The ridge probably starts at the upland island near the center of the northwest edge of the peatland and runs southeastward to the elongate upland island along the southeast edge of the peatland. The southern peatland unit with intricate pools occupies the southern hydrologic area; the central and northern peatland units, the northern hydrologic area. The northern area drains to the Hay Brook outlet. For the southern area, the drainage is less clear but most likely runs southwestward toward the southwestern extremity of the peatland.

Hatham Bog's evaluation total score ranked tenth out of 17 (Table 15) because its eccentric units were used for rating exemplariness and they were only fair in that regard. That approach is inappropriate for Hatham Bog. This bog is special by virtue of its combination of peatland types (raised bog with pools: type 6b in Table 2; plus eccentric units), unique pool arrangement, and hydrologic features. When the 6b unit is used for rating exemplariness, the evaluation score is 51.3 (53.3). In that context it should receive high priority for Critical Area designation.

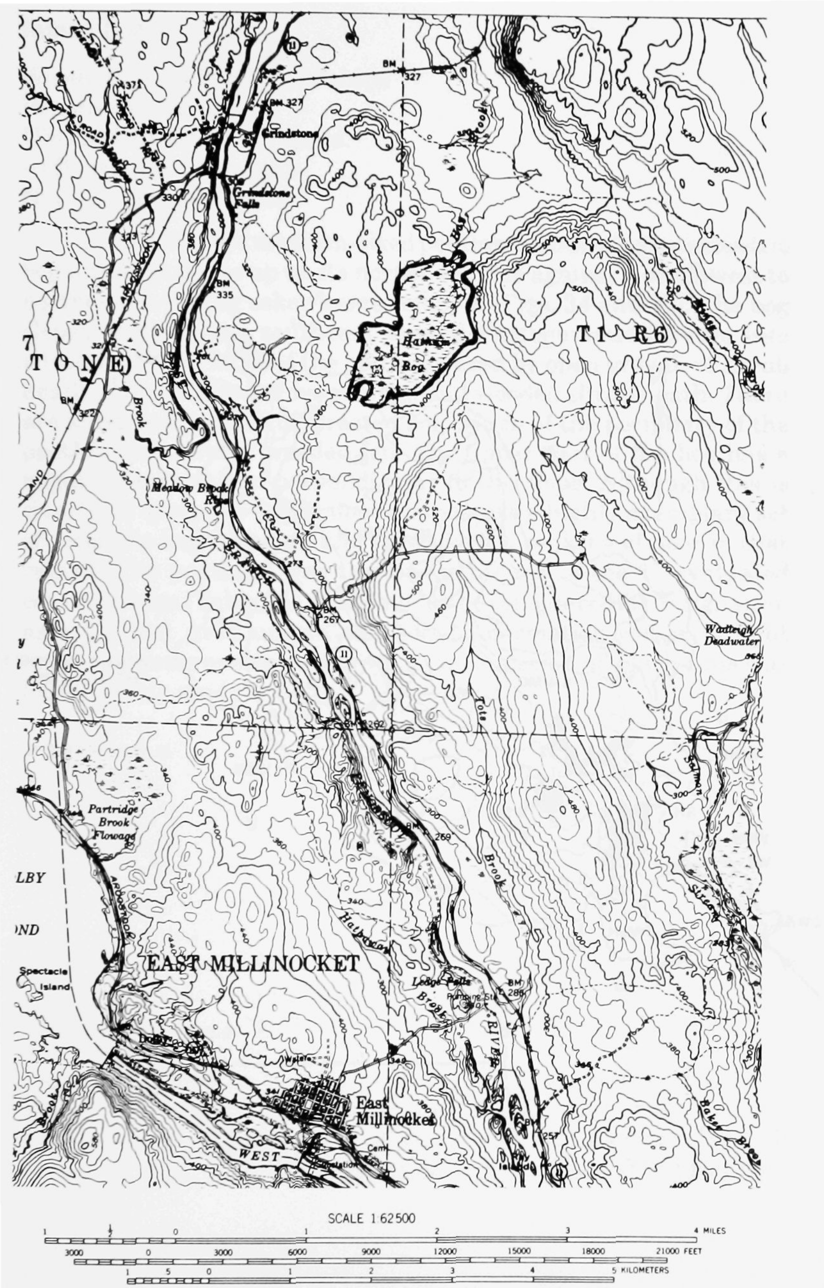


Figure 32. Hatham Bog. Study area outlined on USGS Millinocket 15' quadrangle.

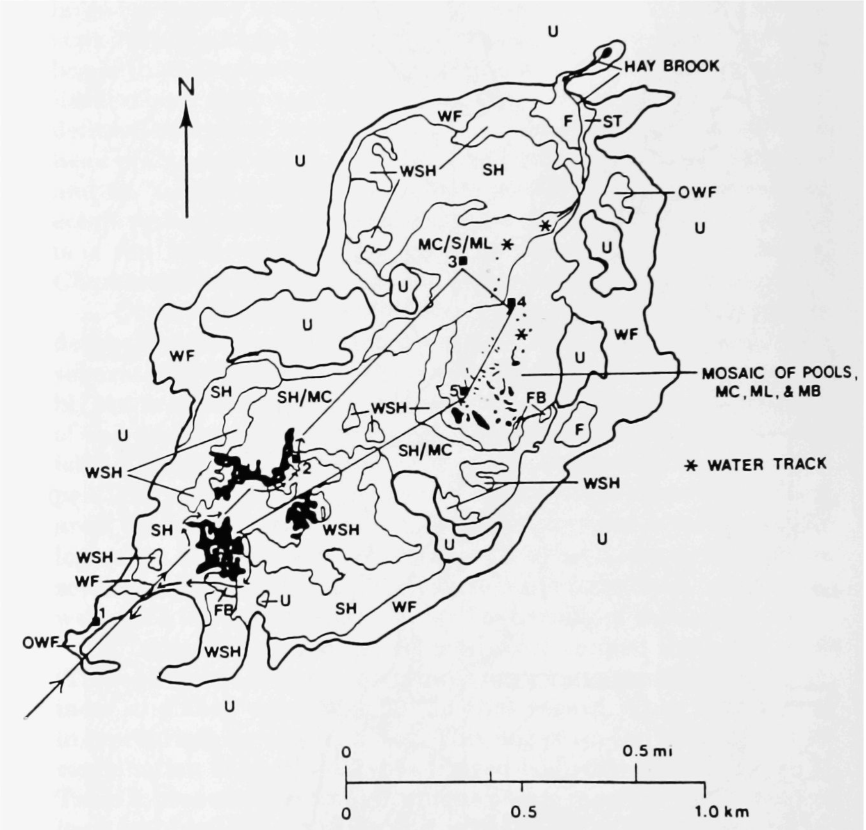


Figure 33. Plan map of Hatham Bog. See Figure 21 caption.

Inman Bog

Woodville and T2R9 Townships
Penobscot County
USGS Millinocket 15' Quad.
~469 acres on plan map
Not now recommended

Inman Bog is a medium-sized peatland containing an eccentric bog unit that backs up on its northwest side against a southwest to northeast trending esker/kame complex (Figs. 34 and 35). The bog slopes down to the southeast toward Pattagumpus Stream into which it drains. Most of the bog is covered by open growth of shrub heath, *Chamaedaphne* moss lawn, and wooded shrub heath. There are scattered patches of forested bog. Much of the periphery of the peatland consists of wooded fen. The upper part of the bog has a vague linear pattern perpendicular to the slope. Although this is clearly an eccentric bog, it does not possess a highly exemplary set of eccentric bog features, and it received a ranking of poor in that regard. The peatland was the lowest ranked of the 17 evaluated eccentric bogs (Table 15). It should not be considered for designation as a Critical Area unless additional information comes to light regarding some special feature (e.g., rare species, of which none was found in this study).

Figure 34. Inman Bog. Study area outlined on USGS Millinocket 15' quadrangle.

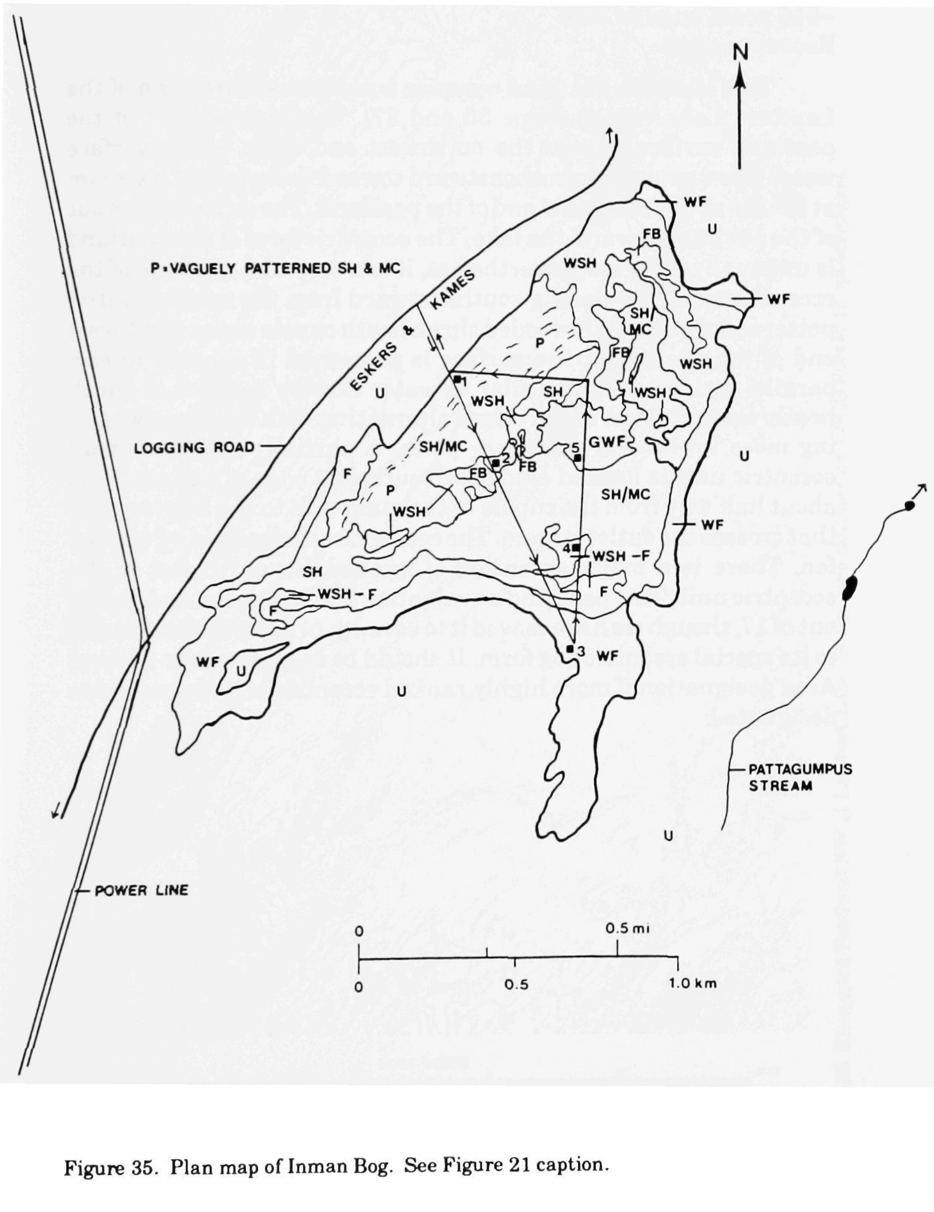


Figure 35. Plan map of Inman Bog. See Figure 21 caption.

Peatland Northwest of Lambert Lake

T11R3N and T1OR3N Townships
Washington County
USGS Forest 15' Quad.
~516 acres on plan map
Recommended

This elongate peatland occupies a northwest extension of the Lambert Lake trough (Figs. 36 and 37). The highest part of the peatland surface is near the northwest end, from which surface water flows generally southeastward toward the origin of a stream at the fen at the southeast end of the peatland. The stream flows out of the peatland toward the lake. The eccentric form of the peatland is unusually elongate; nevertheless, it is a very fine example of the eccentric type. Proceeding southeastward from the relatively dry, patterned shrub heath/wooded shrub heath cupola at the northwest end of the open area, the surface is patterned in roughly linear/parallel fashion perpendicular to water flow by a series of shrub heath/wooded shrub heath ridges alternating with troughs containing moss lawns and secondary pools. A partially separate small eccentric unit is located along the southwest edge of the peatland about half way from the cupola of the main unit to the logging road that crosses the outlet stream. The eccentric unit is edged by wooded fen. There is a major extension of wooded fen northwest of the eccentric unit. This peatland's evaluation total score ranked eighth out of 17, though we have moved it to seventh priority (Table 15) due to its special eccentric bog form. It should be considered for Critical Area designation if more highly ranked eccentric bogs cannot be so designated.

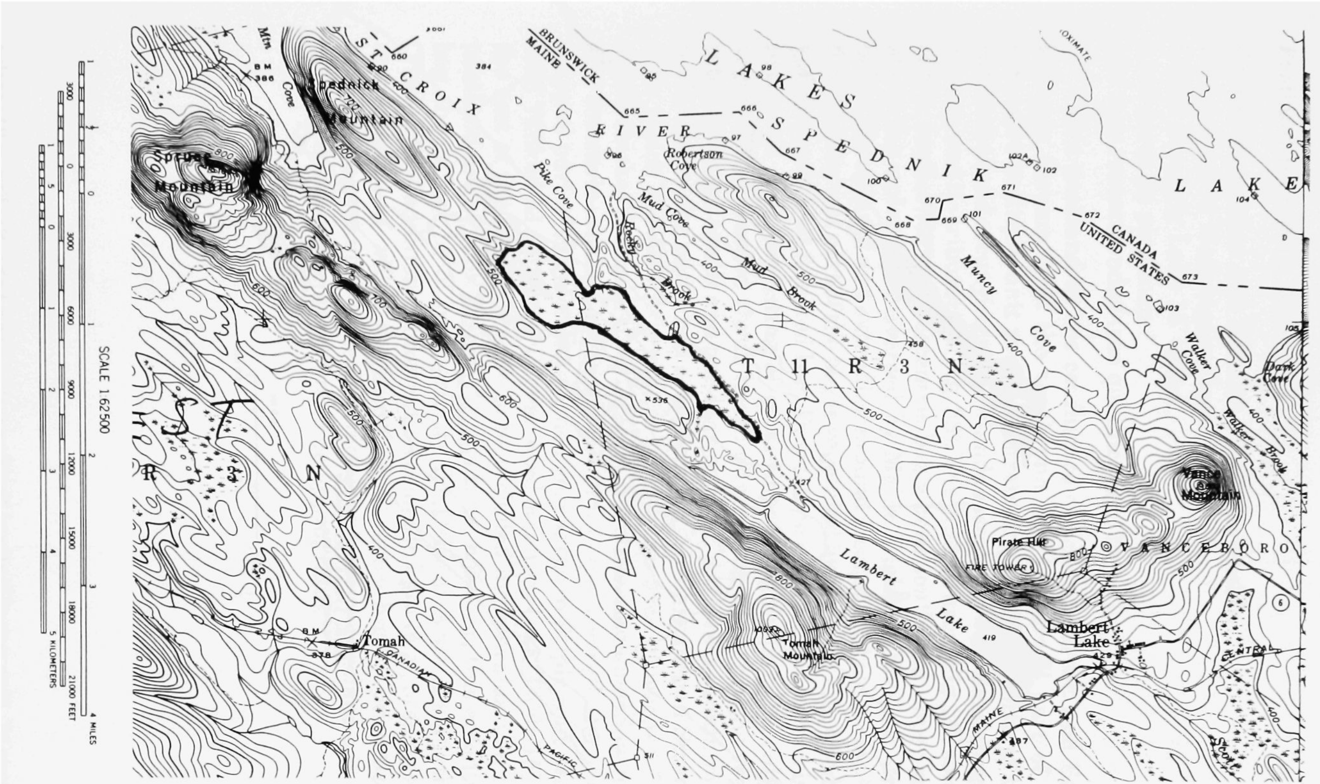


Figure 36. Elongated Peatland NW of Lambert Lake. Study area outlined on USGS Forest 15' quadrangles.

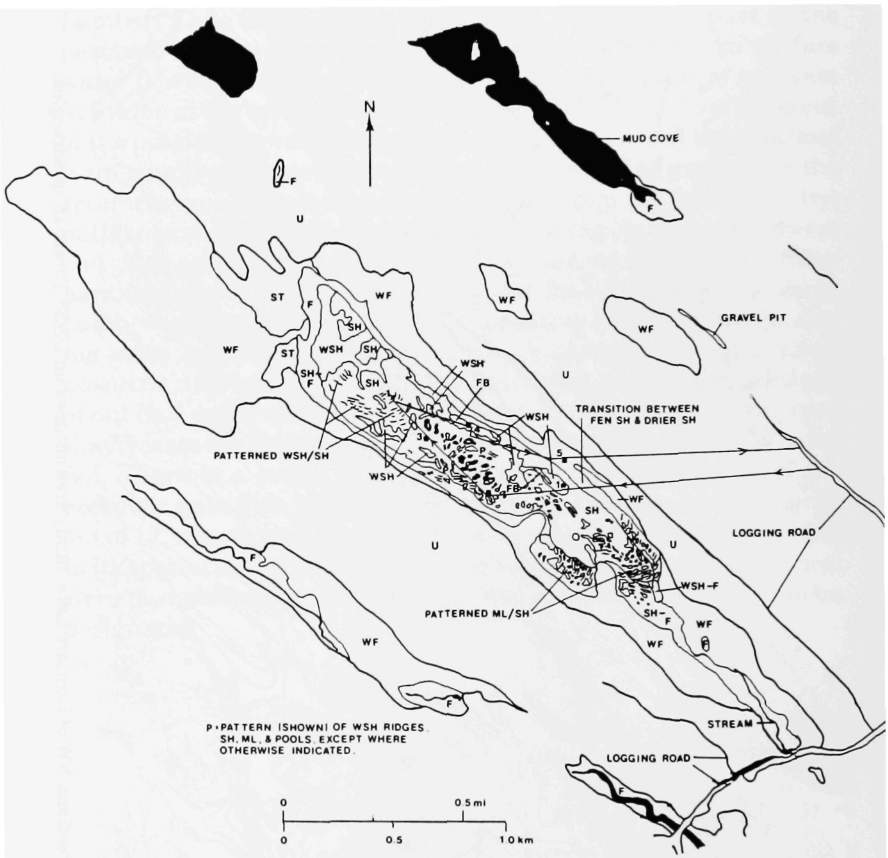


Figure 37. Plan map of Peatland Northwest of Lambert Lake. See Figure 21 caption.

Peatland at Lindsey Brook

Carroll Plantation and Kossuth (T7R2) Township
Penobscot and Washington Counties
USGS Scraggly Lake 15' Quad.
~546 acres on plan map
Not now recommended (see qualification, below)

This peatland at the confluence of Lindsey Brook and Baskahegan Stream is at the south end and is a small part of an extensive multiple-unit peatland stretching ca. 6 km north of the confluence and occupying the lowlands associated with Baskahegan Stream and its tributaries (Fig. 38). The studied area (Fig. 39) south of the confluence is an eccentric bog whose south and upper side abuts the upland transversed by Maine Highway Route 6. Just below the upland, and extending around most of the bog, is wooded fen. The highest part of the bog is vegetated by shrub heath, wooded shrub heath, and forested bog. Downslope and northeastward is a patterned area consisting of cross-slope, roughly parallel ridges vegetated by wooded shrub heath alternating with troughs vegetated by shrub heath and moss lawn and in some cases containing pools. Below the patterned area, and toward Baskahegan Stream (into which the eccentric unit drains), is an area of wooded fen, shrub thicket fen, and shrub thicket fen/streamside meadow fen. The eccentric unit is a good example of its type. Overall, the plan-mapped part of the aforementioned very large multiple-unit peatland ranked 13 out of the 17 evaluated eccentric bogs (Table 15). If the rest of the peatland were to be included in an evaluation, the peatland might rank higher. At this time, however, this eccentric bog should not be of high priority for Critical Area designation (Table 15). If additional information comes to light (e.g., presence of rare species, of which we found none), more highly prioritized eccentric bogs cannot be designated, or the entire peatland can be evaluated, reconsideration would be appropriate.

Figure 38. Peatland around confluence of Lindsey Brook and Baskahegan Stream. Study area outlined on USGS Scraggly Lake 15' quadrangle. Part of Springfield quadrangle is added on the west to show full extent of multiple-unit peatland.

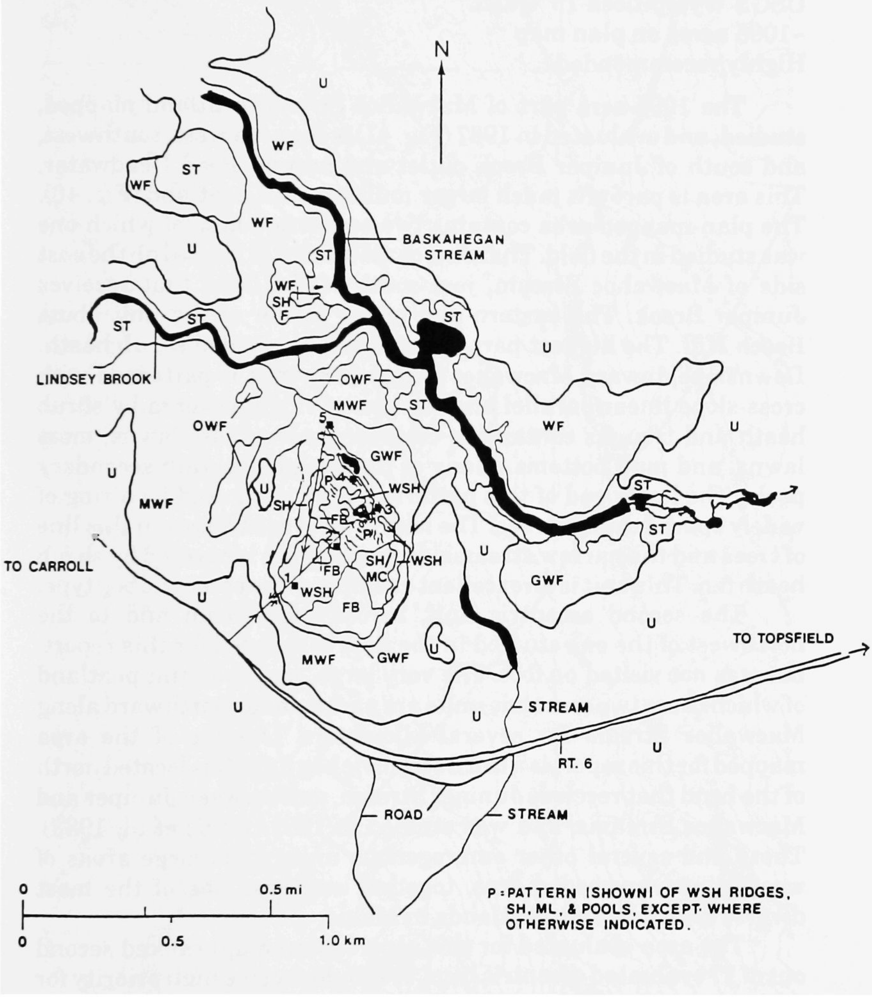


Figure 39. Plan map of Peatland at Lindsey Brook. See Figure 21 caption.

Peatland at Macwahoc Stream

Upper Molunkus and North Yarmouth Academy Grant Townships
Aroostook County
USGS Wytopitlock 15' Quad.
~1095 acres on plan map
Highly recommended

The 1095-acre part of Macwahoc Stream peatland mapped, studied, and evaluated in 1987 (Fig. 41) is the area west, southwest, and south of Juniper Brook outlet and around Reed Deadwater. This area is part of a much larger multiple-unit peatland (Fig. 40). The plan-mapped area contains two eccentric units, of which one was studied in the field. That one, ca. 250 acres, is located on the east side of Macwahoc Stream, just south of the bend that receives Juniper Brook. The eastern and upper border of the unit abuts Beech Hill. The highest part is vegetated by wooded shrub heath. Downslope, toward Macwahoc Stream, the unit is patterned with cross-slope linear/parallel alternations of ridges covered by shrub heath and troughs containing *Chamaedaphne* moss lawns, moss lawns, and mud bottoms. Many of the troughs contain secondary pools. The lower end of this patterned area is marked by a ring of widely spaced conifer trees. The nearly level area between this line of trees and the narrow streamside meadow fen is covered by shrub heath fen. This unit is an excellent example of the eccentric bog type.

The second eccentric unit, across the stream and to the northwest of the one studied in the field is mapped for this report, but was not visited on foot. The very large, multiple-unit peatland of which these two eccentric units are part extends northward along Macwahoc Stream for several kilometers. Outside of the area mapped for this report is a third eccentric bog unit. It is located north of the bend that receives Juniper Stream, and between Juniper and Macwahoc Streams, and was studied in 1982 (Davis et al. 1983). These and several other ombrogenous units, plus large areas of wooded and unwooded fens, together comprise one of the most diverse multiple-unit peatlands in Maine.

The area evaluated for this report (plan map) ranked second out of 17 evaluated eccentric bogs. It should receive high priority for designation as an eccentric bog Critical Area, second only to the bog at Cold Stream (Table 15). If the entire multiple-unit peatland at Macwahoc Stream were to be considered, we would put it above Cold Stream in position of highest (first) priority.

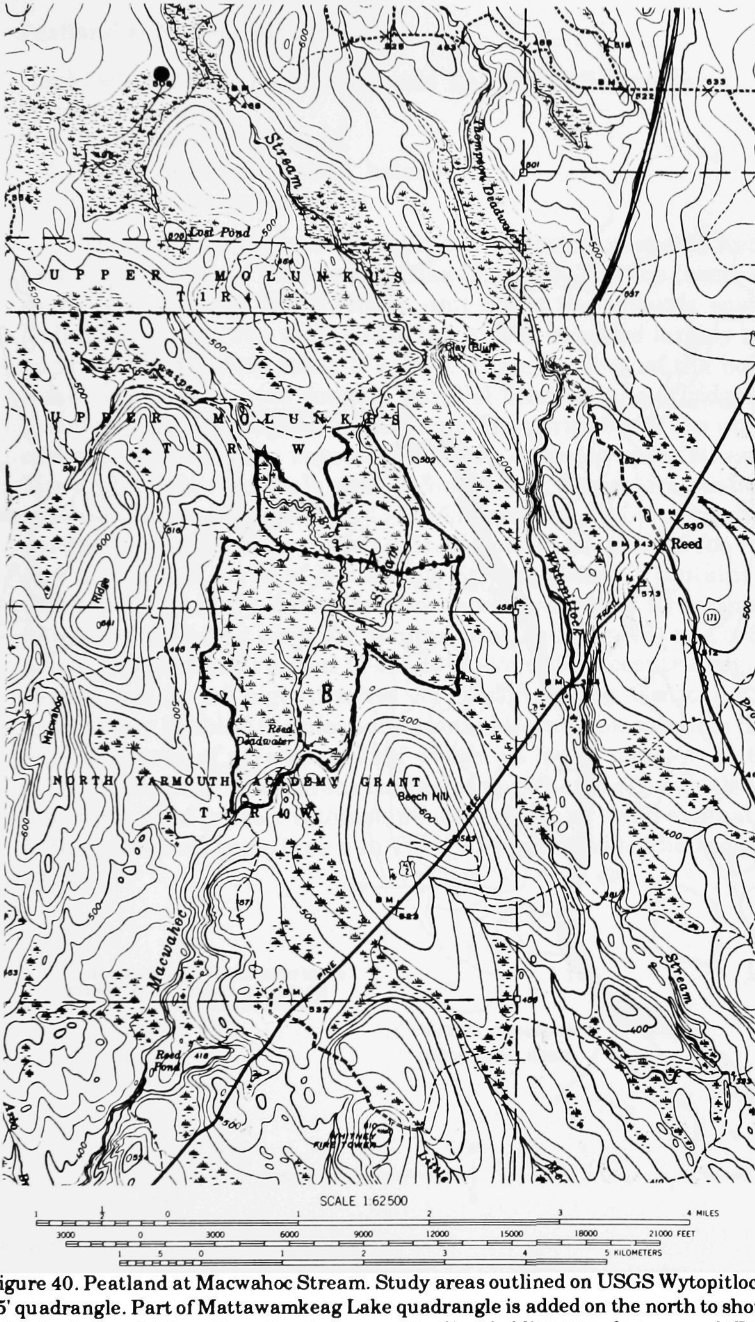


Figure 40. Peatland at Macwahoc Stream. Study areas outlined on USGS Wytopitlock 15' quadrangle. Part of Mattawamkeag Lake quadrangle is added on the north to show full extent of multiple-unit peatland. Area south of beaded line was plan mapped (Fig. 41) for this report. Field studies were carried out on two areas outlined by dashes: A—1983 (Davis et al. 1983), and B—1987 (this study).

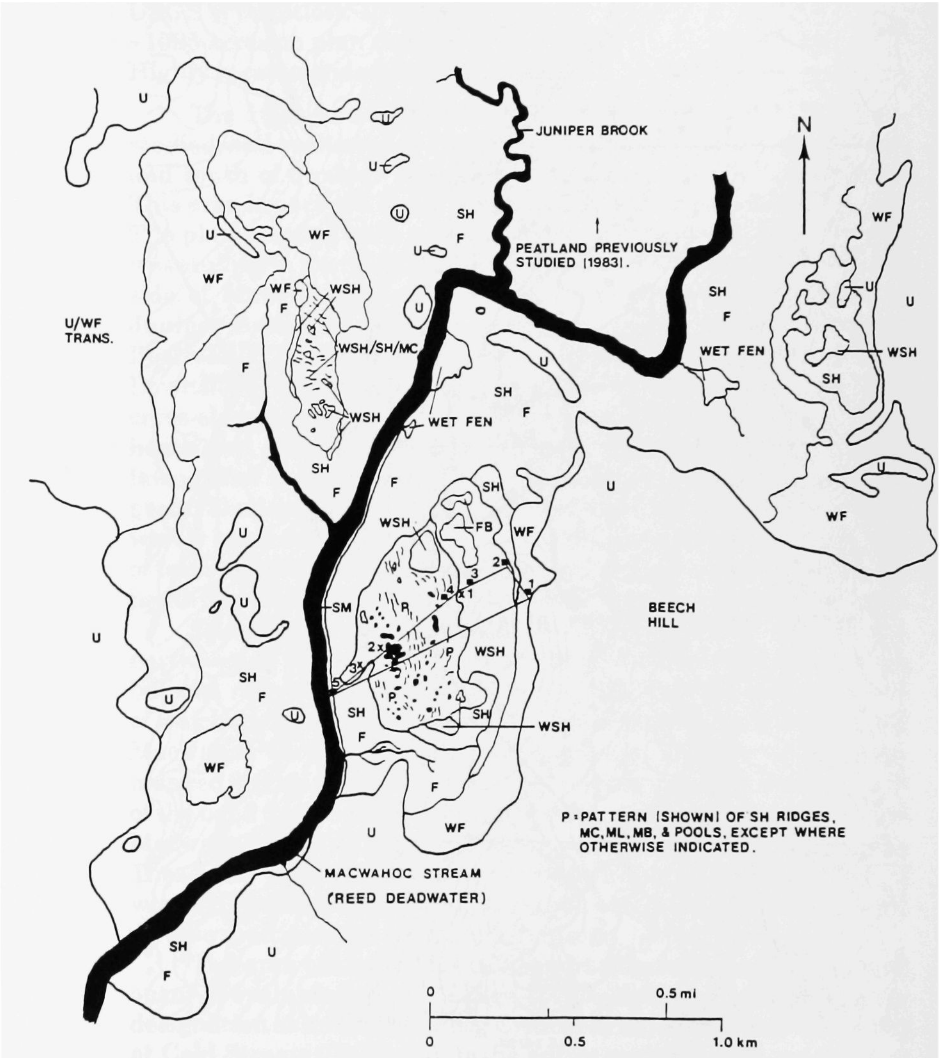


Figure 41. Plan map of Peatland at Macwahoc Stream. See Figure 21 caption.

Peatland at Nollesemic Stream

Hopkins Academy Grant (East) and TAR7 WELS Townships
Penobscot County
USGS Millinocket 15' Quad.
~484 acres (see qualification, below)
Not now recommended

This peatland is located about one kilometer east and southeast of the outlet of Nollesemic Lake (Fig. 42). The top (west and southwest sides) of the eccentric unit abuts the uplands east of Nollesemic Lake. The east side of the unit is bounded largely by a north-south trending esker (Fig. 43). The open area of the bog is weakly patterned with roughly parallel alternations of ridges of shrub heath and troughs of moss lawn. The periphery of the unit is covered by wooded fen vegetation, and by open fen along streams. The unit is a fair example of an eccentric bog. The entire peatland south of the logging road (Fig. 43) covers ca. 484 acres. A constricted part of the peatland around Mud Brook continues north of the road and widens out north of Nollesemic Stream where it contains an excellent example of a kettle (ice block depression) with a schwingmoor fen. Along with that part, the mapped peatland (Fig. 43) covers 657 acres. The peatland ranked 14 out of 17 evaluated eccentric bogs. It should not be of high priority for eccentric bog Critical Area designation (Table 15) unless additional information comes to light (e.g., presence of rare species, of which we found none) or unless more highly prioritized areas cannot be designated. The kettlehole fen might be of greater interest, pending inventory and evaluation of that peatland type (type 4 in Table 2) on statewide and regional bases.

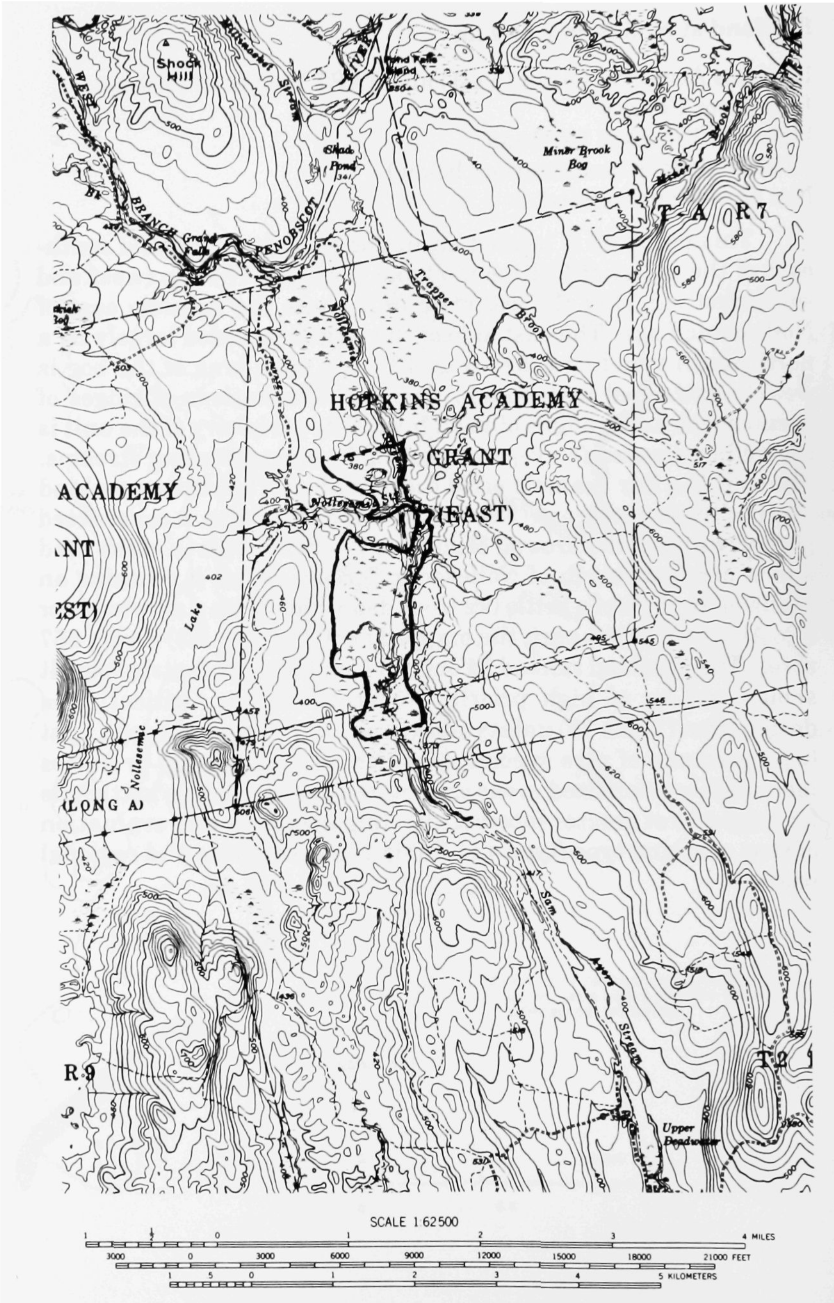


Figure 42. Bog and kettle at Nollesemic Stream and Mud Brook. Study area outlined on USGS Millinocket 15' quadrangle.

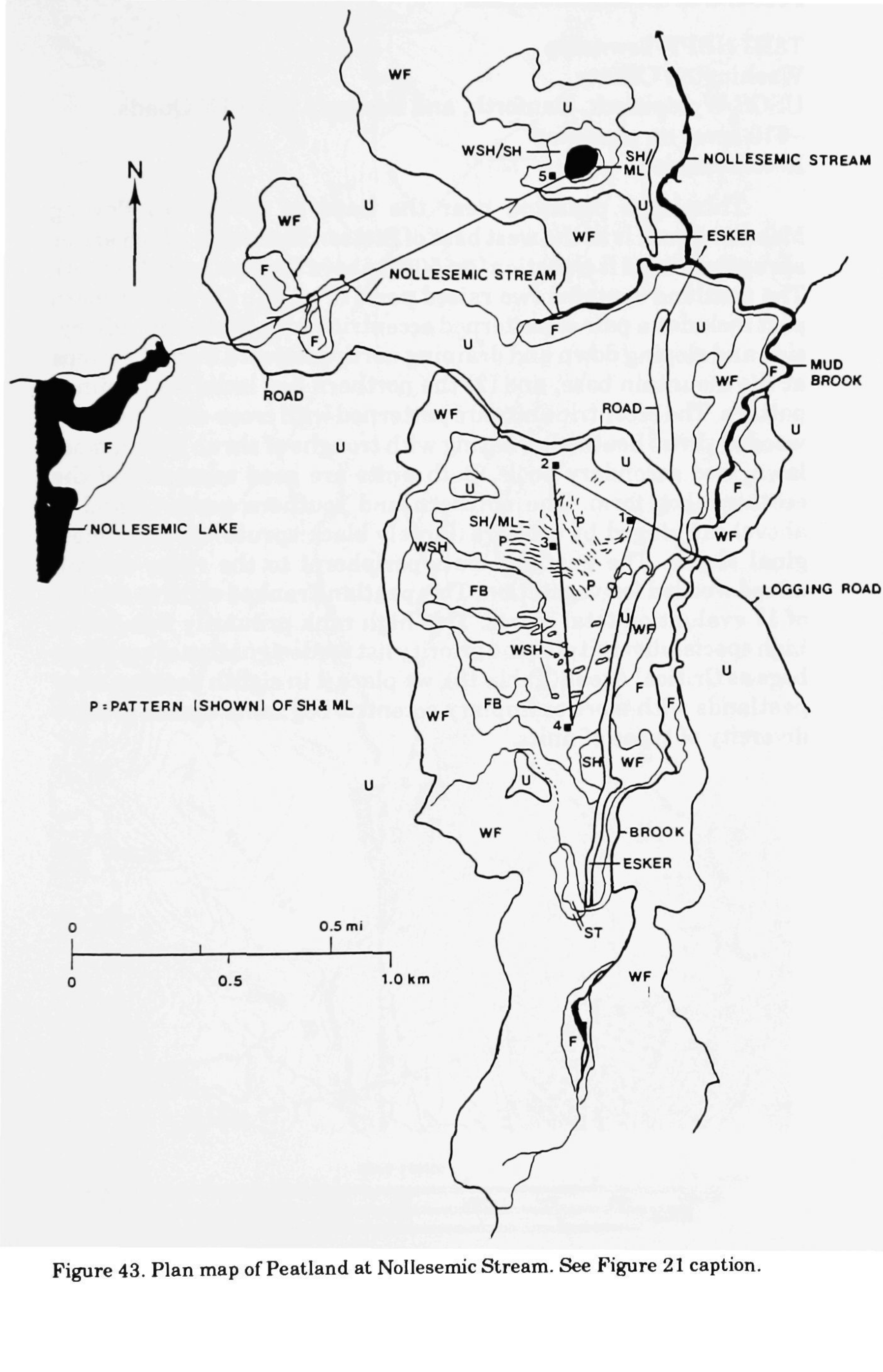


Figure 43. Plan map of Peatland at Nollesemic Stream. See Figure 21 caption.

Peatland at Stetson Mountain

T8R3 NBPP Township
Washington County
USGS Wytopitlock, Danforth, and Scraggly Lake 15' Quads.
~610 acres on plan map
Recommended

This large peatland near the head of northward flowing Meadow Brook is at the west base of Stetson Mountain which arises abruptly to 1095 ft elevation (ca. 500 ft above the peatland) (Fig. 44). The peatland contains two raised parts (Fig. 45): (1) the southern part includes a pair of patterned eccentric units, coalesced side-by-side and sloping down and draining northwestward from their tops at the mountain base, and (2) the northern bog lacks well-defined pattern. The eccentric units are patterned with cross-slope ridges of wooded shrub heath alternating with troughs of shrub heath, moss lawn, and secondary pools. Both units are good examples of the eccentric bog form. The northern and southern parts (1 and 2, above) are ringed by conifers (largely black spruce) on their marginal slopes. The peatland flats peripheral to the rings contain mixed wooded fen vegetation. This peatland ranked sixth in the list of 17 evaluation total scores. This high rank primarily was due to high species diversity. In the priority list for designation of eccentric bogs as Critical Areas (Table 15), we place it in eighth position after peatlands with more exemplary eccentric bog units and/or greater diversity of types of units.

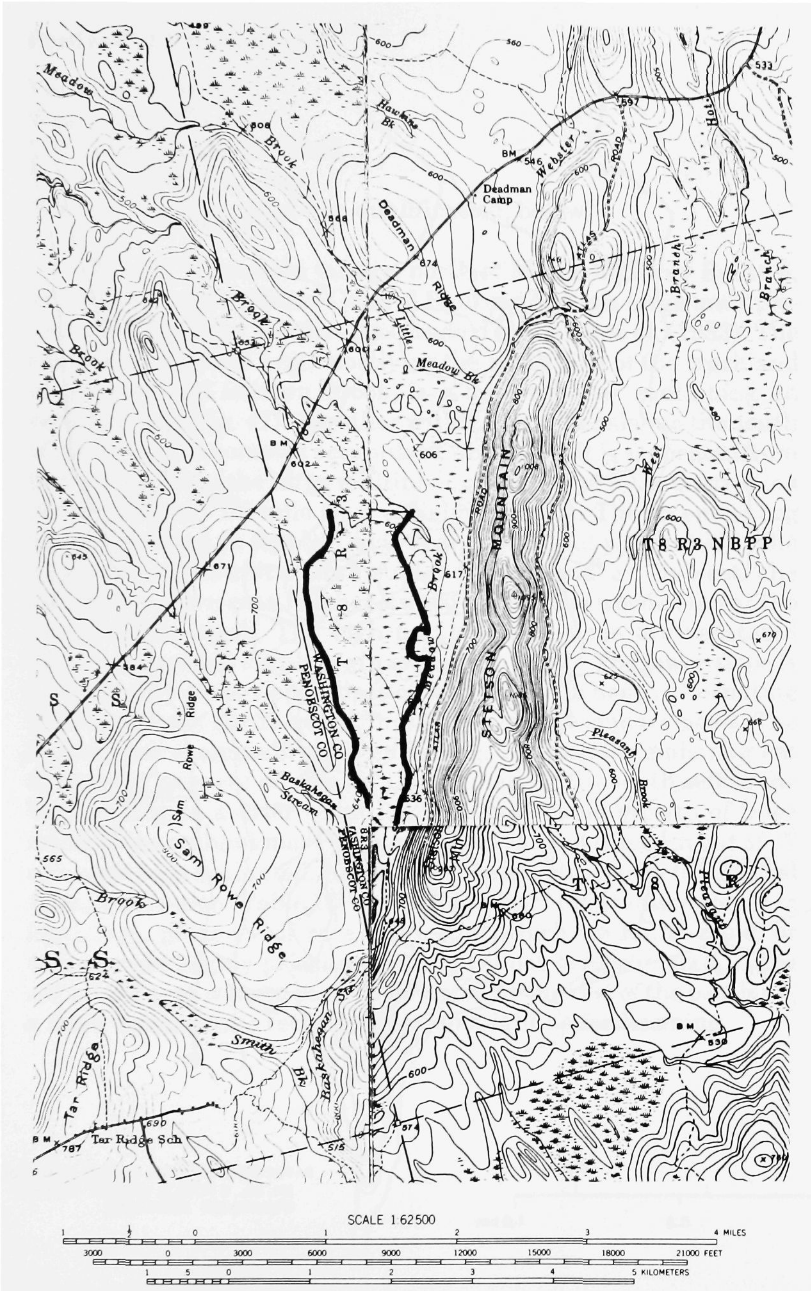


Figure 44. Peatland at West Base of Stetson Mountain. Study area outlined on USGS Wytopitlock, Danforth, Springfield, and Scraggly Lake 15' quadrangles.

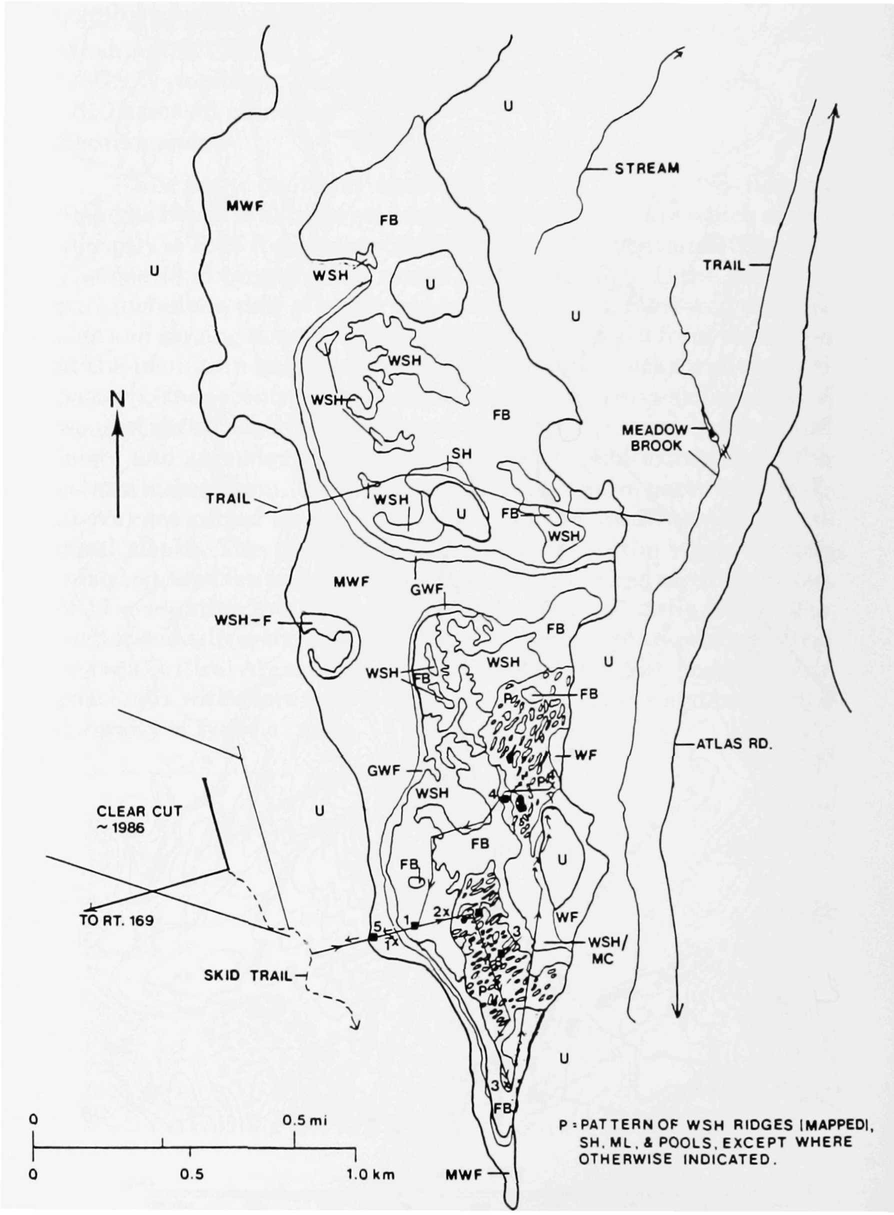


Figure 45. Plan map of Peatland at Stetson Mountain. See Figure 21 caption.

Peatland at Vanceboro RR

Vanceboro Township
Washington County
USGS Vanceboro 15' Quad.
~489 acres on plan map
Not now recommended (see qualification, below)

West of Vanceboro village, north of Maine highway Route 6, and straddling the Maine Central Railroad line is a large multiple-unit peatland (Fig. 46) that was studied by Davis et al. (1983). The easternmost raised unit, mostly on the north side of the track and at the origin of Salmon Brook, is a mire complex containing an eccentric bog (Fig. 47). Together with its fen extension to the south of the track, the complex occupies ca. 489 acres. It is separated from the remainder of the large multiple-unit peatland by a constriction in the peatland 1/2 mile west of Salmon Brook. The eccentric bog was not studied on foot by Davis et al. (1983), but was in 1987. The upper part of the unit abuts an upland "peninsula" on the west. The unit slopes down east-northeastward toward the wooded fen at the origin of the brook. The high part and mid-slope are vegetated largely by wooded shrub heath and shrub heath. The lower slope is patterned by cross-slope ridges of wooded shrub heath alternating with troughs of shrub heath, moss lawn, and secondary pools. The unit is a fair example of an eccentric bog. The railroad embankment appears to have cut off some of the drainage to the south side of the bog, leading to a drier condition and more rapid growth of trees south of the embankment. This peatland ranked fifteenth out of 17 eccentric bogs evaluated. It should not be a high priority for Critical Area designation (Table 15) unless additional information comes to light (e.g., presence of rare species, of which we found none) or unless more highly prioritized areas cannot be designated. If the evaluated area were to be supplemented by the rest of the peatland, a more enthusiastic recommendation might be forthcoming.

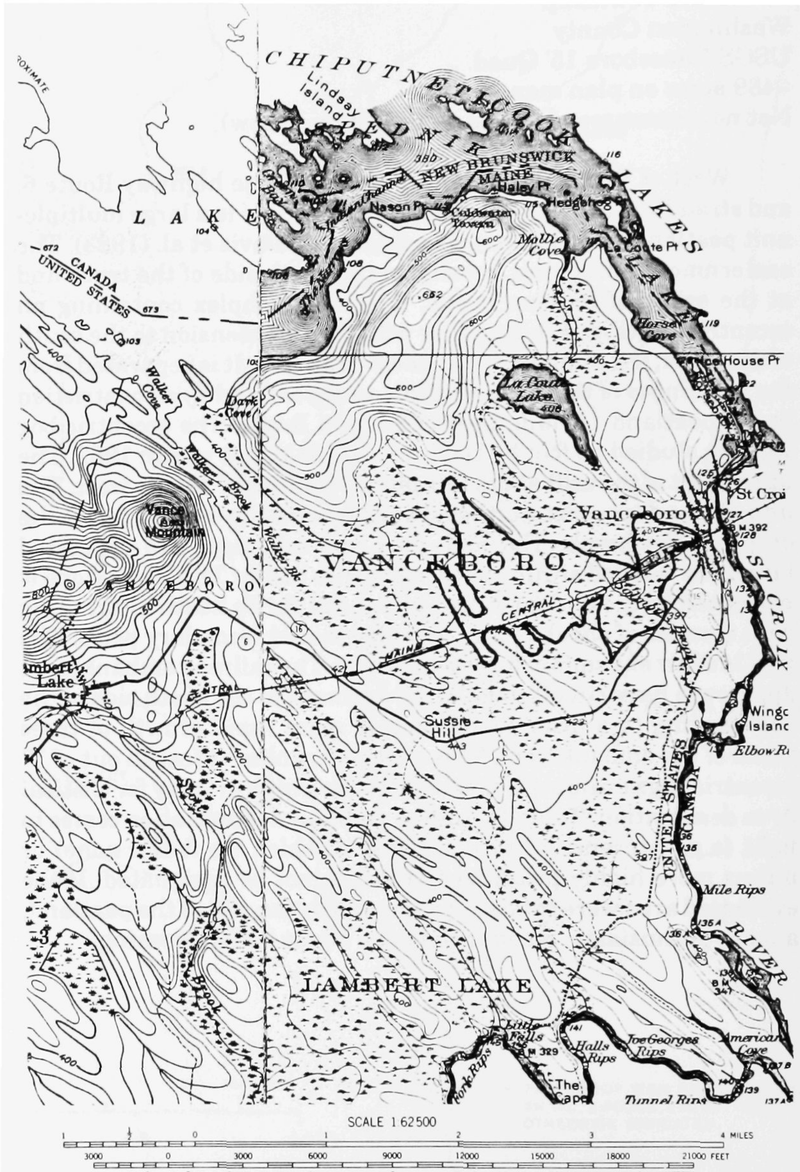


Figure 46. Peatland at Origin of Salmon Brook, just west of Vanceboro RR Yard. Study area outlined on USGS Vanceboro 15' quadrangle. Part of Forest quadrangle added on the west to show full extent of the multiple-unit peatland.

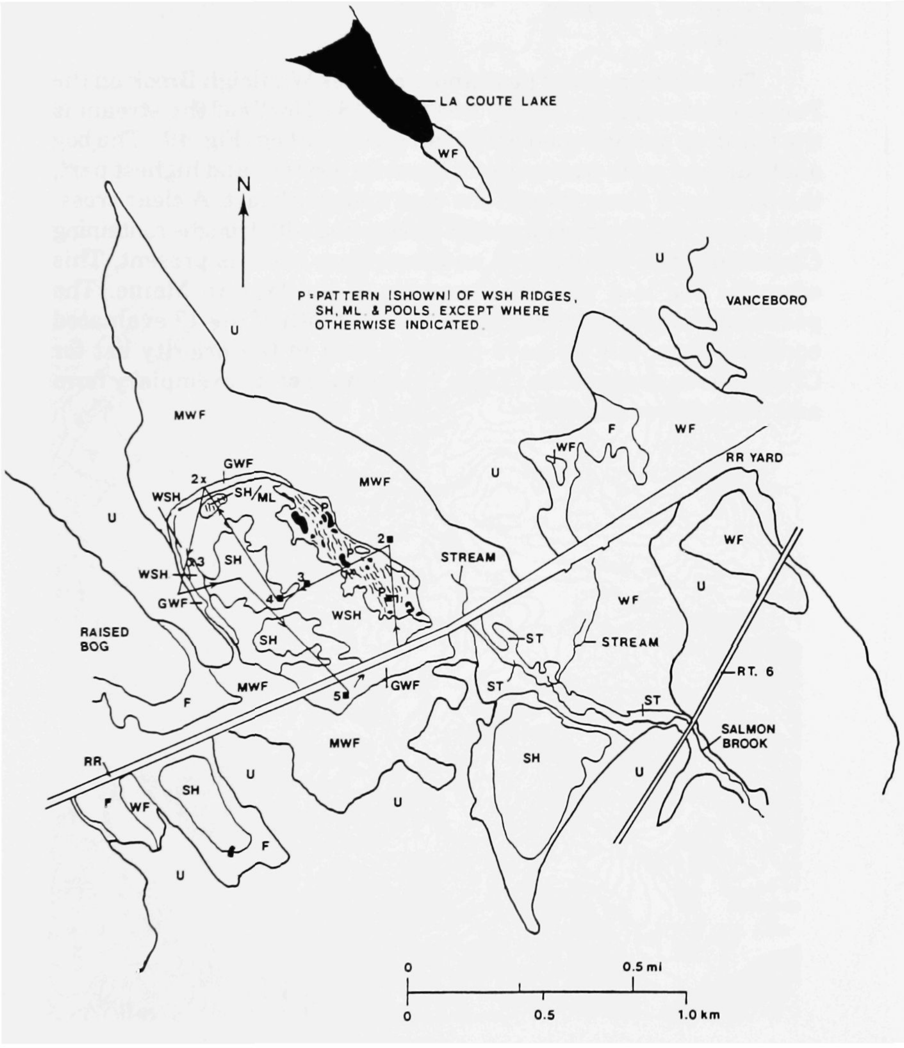


Figure 47. Plan map of Peatland at Vanceboro RR. See Figure 21 caption.

Wadleigh Bog

T7R6 WELS and T7R5 WELS Townships
Penobscot and Aroostook Counties
USGS Island Falls and Oxbow 15' Quads.
~454 acres on plan map
Recommended

This medium-sized peatland straddles Wadleigh Brook on the Penobscot/Aroostook County line (Fig. 48). North of the stream is the teardrop shaped open part of an eccentric bog (Fig. 49). The bog abuts upland at its western end. From its western and highest part, the bog slopes down toward the east and southeast. A clear cross-slope pattern of shrub heath ridges alternating with troughs containing *Chamaedaphne* moss lawns and secondary pools is present. This eccentric bog is a very fine example of the type in Maine. The peatland's evaluation total score ranked ninth of the 17 evaluated eccentric bogs, but we have placed it fifth in the priority list for Critical Area designation (Table 15) because of its exemplary form and discrete boundaries.

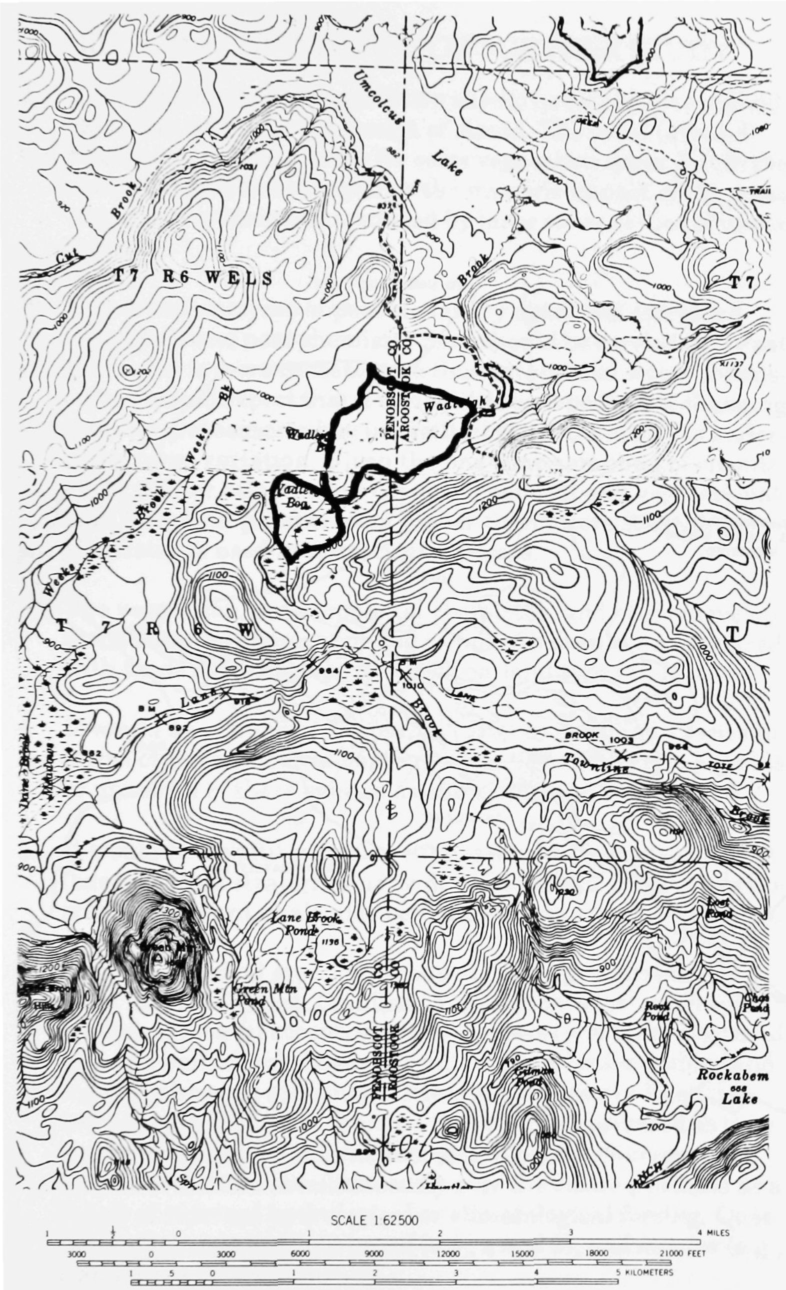


Figure 48. Wadleigh Bog. Study area outlined on USGS Island Falls and Oxbow 15' quadrangles.

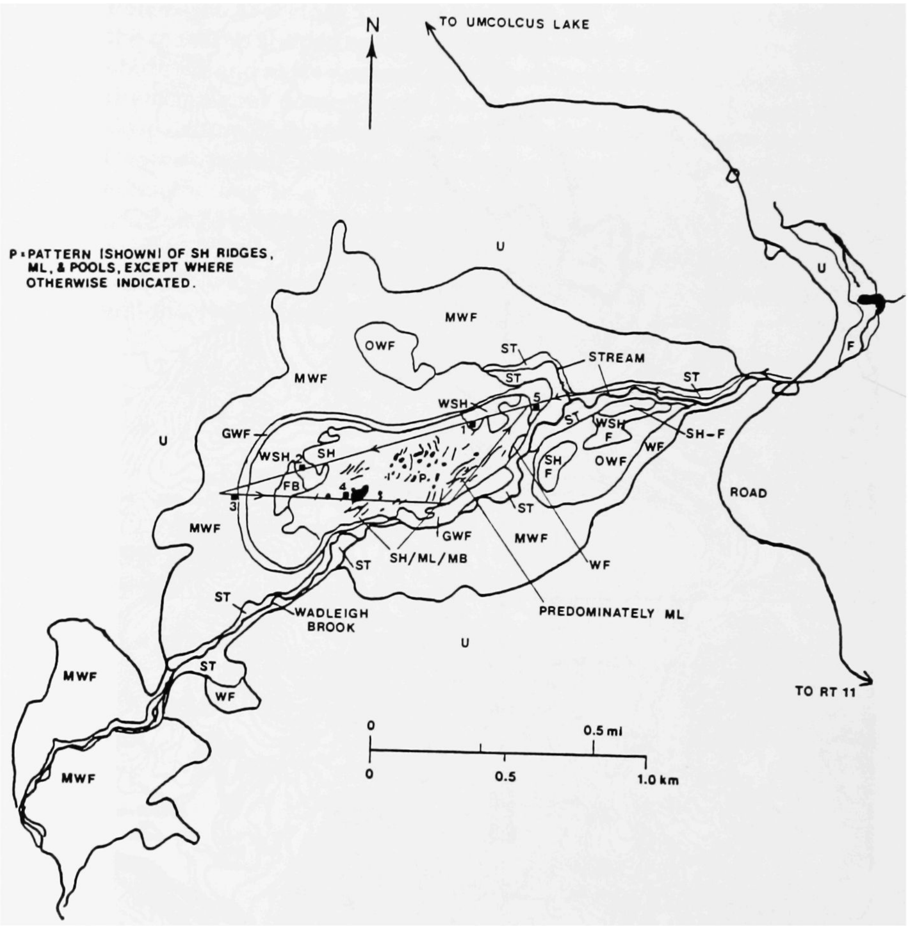


Figure 49. Plan map of Wadleigh Bog. See Figure 21 caption.

RECOMMENDATIONS FOR FURTHER STUDY

1. Numerical analyses of vegetation should be extended to individual strata and selected groups of strata. The moss (ground) stratum may be diagnostic for some vegetation types, but in the analyses of all strata together the numeric impact of the moss stratum may have been reduced by large cover values of upper strata.

2. Numerical analyses of peat chemistry data, and combined vegetation and peat chemistry data should be carried out. Peat chemistry is more conservative than interstitial water chemistry; we would expect that it varies little over periods of changing weather and season when interstitial water chemistry is undergoing large variation. Given the one-time sampling of chemistry, a tighter relationship between chemical and vegetational data may emerge when peat rather than interstitial water chemistry is used in numerical analyses.

3. The vegetation, environmental chemistry, and origin/development patterns of eccentric bog complexes should be compared with those same aspects of other peatland types in Maine.

4. It would be of interest to characterize key peatland species in terms of their chemical environments. It may then be possible to use some of these species as environmental indicators.

5. It would be helpful to future studies of peatland development (based on peat stratigraphic evidence) in Maine to complete the study of modern analogues begun by Davis and Hu (in prep.).

6. The only detailed study of eccentric bog origins and development lacks ^{14}C dates. Detailed ^{14}C-based chronostratigraphic studies of several eccentric bog complexes (and other peatland types as well) should be carried out to gain a better understanding of hydroseral sequences. These sequences are likely to include both autogenic changes, that may be expressed as time-transgressive zonal migrations, and allogenic changes, that may be evidenced simultaneously over the entire peatland as a result of external hydrological or climatological forcing. Questions of interest are both broad (e.g., a and b), and narrow (e.g., c and d), as follows.

a. Are recurrence horizons present, or are there other indications of widespread changes in peatlands that resulted from past changes in climate? Independent evidence of past climate change would come from paleoecological studies of upland vegetation, viz. palynological analyses of cores from several lakes in the region. Some of these data are already available (G.L. Jacobson et al. pers. comm.).
b. Based on these results, can we predict the effects on peatlands of future changes in climate resulting from increased concentrations of "greenhouse gases"?
c. Did eccentric bog complexes originate and coalesce from separate peat nuclei in separate small basins?
d. Can the postulated origin by paludification of some parts of eccentric bog complexes be confirmed by plant macrofossil analyses of earliest peats?

7. When studies of other peatland types and their evaluations are completed for Maine, the evaluation of all types should be placed on the same scale for comparison. However, it would be unwise to delay the Critical Area designation or protection of highly recommended eccentric bogs until that comparison can be made because unpredictable development pressures may result in Critical Area destruction or degradation.

8. The consideration of any wetland (bog, fen, swamp, marsh) for Critical Area designation or for protective or reserve status should include recognition that a wetland is part of a larger catchment from which runoff entering the wetland is derived. Our study and recommendations have not taken this into consideration. Formal action toward Critical Area designation should include the gathering of information on catchment boundaries, characteristics, and management that will protect the wetland from degradation. Preferably, entire catchments should be designated and/or protected when wetlands are concerned.

SUMMARY AND CONCLUSIONS

1. Eccentric bogs are rare in the United States. Out of an estimated total of 35 in the nation (excluding Alaska, for which no information could be found), all are in Maine. Of the ca. 35, 22 have been confirmed on air photos, 20 of these by aerial reconnaissance, and 17 of these by field study.

2. Eccentric bogs have not been recognized by the recent Canadian Wetland Classification System (NWWG 1988), but they probably do exist, in unknown number, in Canada's Atlantic Boreal Wetland Region.

3. Eccentric bogs are a well-known boreal peatland type, occurring in Europe including Scotland. The type is common in parts of Sweden, Finland, and the adjacent part of the Soviet Union.

4. In Maine, eccentric bogs occur, with one known exception (Greenville), in the eastern two-fifths of the state, from the Millinocket area to New Brunswick, north of Bangor and south of Ashland.

5. The topography of Maine's eccentric bog zone is hilly. The altitudes are generally between 150 and 1500 ft a.s.l. The zone was glaciated during the Pleistocene, most recently becoming free of glacial ice 12,000–13,000 ^{14}C years ago. The eccentric bogs are located at low altitudes. The deepest organic deposits in these bogs mostly lie on glaciolacustrine clay-silt (glacial rock flour). This clay-silt and the till and bedrock of the surrounding uplands are generally siliceous/granitic, and give rise to soft, oligotrophic waters.

6. The climate of the eccentric bog zone is basically continental but the zone is exposed to maritime air masses part of the time. Annual precipitation is about 100 cm, mostly as snow from December through March. July and January mean temperatures are, respectively, 19° and -10°C. Annual evapotranspiration is about half annual precipitation. Moisture excess from 1 May through October ranges around 10–14 cm.

7. Eccentric bogs are true bogs, that is they possess a major ombrotrophic area. (In this report, and henceforth in this section true bogs are simply called bogs.) Nevertheless, all eccentric bogs have peripheral areas of fen (minerotrophic). The ombrotrophic portion of these peatland (mire) complexes is called the bog proper.

8. Eccentric bog complexes occur on the gentle slopes rising from valley bottoms. The surface of the bog proper slopes primarily in one direction; the upslope end abuts or nearly abuts mineral upland, and the downslope end borders fen. The distant end of the fen usually borders a lake or stream. There is considerable variation from one peatland to the next around these general characteristics.

9. A major part of the surface of the bog proper is patterned with series of parallel troughs and ridges (total microrelief generally ~0.4—~1 m) whose long dimensions are perpendicular to the slope, i.e., along the elevational contours. Some of the troughs are occupied by secondary pools. Most of the rest of the peatland surface has a microtopography of non-linear hummocks and hollows.

10. The 17 eccentric bog complexes that have been studied in the field range in area (as plan mapped) from 366 to 4130 acres.

11. All but one of these peatland complexes contain multiple units of more than one geomorphic/hydrologic peatland type, in many cases three types per peatland complex.

12. The peatland complexes include or border a number of landscape features including upland "islands," streams, rivers and lakes, and eskers.

13. The area of the bog proper usually covers about half or less than half of the total area of the peatland complex. Most of the peatland complexes are over half wooded. Digitizer areal analysis of the air-photo-based plan map of each peatland indicates that the bog proper ranges from 8% to 72% (aver. 33%) of total mapped area of the peatland complex (fen 28% to 92%, largely wooded). Linear-patterned areas of the bog proper range from 1% to 19% (aver. 9%) of the mapped complex, and wooded plus semi-wooded areas from 30% to 95% (aver. 75%) of the mapped complex.

14. Thirty-seven to 188 taxa of vascular plants, bryophytes and lichens were tallied by 2- to 4-person teams during periods of 5 to 30.5 hours per peatland complex (aver. 79 taxa in aver. 8.4 hours). A total of 240 different taxa were found at the 15 eccentric bog complexes visited in 1987. Several score of these taxa occurred at all or a large majority of the peatlands. These taxa are common at, and widespread among, Maine's oligotrophic, boreal peatlands. No truly rare species was found, probably because most rare peatland species occur under less acidic and more eutrophic conditions.

15. Based on TWINSPAN analysis of relevé data, 22 specific vegetation types were distinguished. Apart from the streamside meadow type, which is most different from all the others, the types group into the
    a. moss lawns and mud bottom of the bog proper;
    b. shrub heaths, wooded shrub heaths, and forested bog of the bog proper, together with extreme poor open fens;
    c. black spruce/*Sphagnum*/Ericaceae fens; and
    d alder/winterberry/fern fens.
16. DECORANA analysis of the relevé data indicated a vegetational continuum from wooded to unwooded along the first axis. This continuum is correlated with chemical indicators of trophic state, with wooded (fens) at relatively high state. Due to their small quantitative differences, several bog and extreme poor fen vegetation types (as distinguished by TWINSPAN) crowd into the middle of the first axis continuum.
17. Peat interstitial water chemical analyses generally indicated very dilute, acidic waters. The "poor" or oligotrophic character of these waters is similar to extreme poor fen and bog waters in other geographic regions.
18. Principal components analysis of the chemical data indicated a major gradient (first component) from low to high geological/ mineral influence on peatland waters, and another gradient (second component) relating to organic acidity. A majority of samples occurs at the low end of the first gradient. Identification of these samples in terms vegetation clearly indicates the association of bog and extreme poor fen vegetation types with lowest mineral concentrations.
19. The relationships between (a) individual bog and fen plant species and (b) peat interstitial water chemistry are clearly demonstrated by canonical correspondence analysis (CCA).
20. CCA confirms that the major vegetational continuum in the peatlands is along a chemical trophic gradient and that most areas of the peatlands including the fens are oligotrophic.
21. The eccentric bogs contain deep accumulations of peat. Maximum depth per peatland ranged from 5.2 to 8.2 m (aver. max. depth 6.7 m).

22. Only one peatland, Smith Brook Deadwater, has been the subject of detailed stratigraphic study (Perkins 1985) to determine conditions at the time of peatland origin and subsequent stages of development. That study, plus stratigraphic reconnaissance at another 15 eccentric bogs, broadly indicate the origins and the developmental stages of eccentric bogs in Maine. A large majority of the sites are underlain by glaciolacustrine deposits of clay-silt (indicating deposition in a young glacial lake); other sites are underlain by sands and gravels (deposited in more rapidly moving water) or glacial till. At a large percentage of the glacial lake sites, humic-organic lake sediment (dy) is superposed on the clay-silt indicating development of a humic lake with fens forming at the shallowest areas. A large majority of these lake sites then developed into open fen or semi-wooded fen. This process of terrestrializion was the main mode of origin of the eccentric bogs.

23. At a minority of the clay-silt sites and a majority of the sand and gravel sites, a lake stage was absent, and either (a) open or open-wooded fen was the first ecosystem at the site (primary mire formation) or (b) a terrestrial forest ecosystem developed first, to be replaced by wooded fen (paludification). Sequence b is limited to small areas around the edges of the peatlands.

24. Most open and semi-wooded areas of the present bog proper developed from open and semi-wooded fens. Most present fen areas were less wooded during earlier fen stages.

25. Eccentric bog origins and developmental sequences in Maine are typical for North American bogs.

26. The 17 peatlands studied in the field include the most exemplary eccentric bogs in Maine. Based on an objective method of evaluation, ten of the 17 are recommended for Critical Area status. This high proportion (10/17) of study sites is due to the great rarity (probably not more than 35) of eccentric bogs in the conterminous United States. Four eccentric bog complexes are most highly recommended for Critical Area status (Table 15): Cold Stream, Macwahoc Stream, Coffin Bog, and Big Bog, in that order of priority.

LITERATURE CITED

Aaby, B., and B.E. Berglund. 1986. Characterization of peat and lake deposits. In *Handbook of Holocene Palaeoecology and Palaeohydrology*, ed. B.E. Berglund, 231–246. Chichester, U.K.: Wiley.

Barber, K.E. 1981. *Peat Stratigraphy and Climatic Change: A Palaeoecological Test of the Theory of Cyclic Peat Bog Regeneration.* Rotterdam, Neth: Balkema.

Boatman, D.J. 1983. The Silver Flowe National Nature Reserve, Galloway, Scotland. *J. Biogeogr.* 10: 163–274.

Boatman, D.J., and R.W. Tomlinson. 1973. The Silver Flowe. I. Some structural and hydrological features of Brishie Bog and their bearing on pool formation. *J. Ecol.* 61: 653–666.

Bradbury, I.K., and J. Grace. 1983. Primary production in wetlands. In *Ecosystems of the World, v. 4A. Mires: Swamp, Bog, Fen and Moor,* ed. A.J.P. Gore, 285–310. Amsterdam: Elsevier.

Braun-Blanquet, J. 1932. *Plant Sociology: The Study of Plant Communities.* New York: McGraw-Hill.

Bryant Jr., V.M., and R.G. Holloway (eds.). 1985. *Pollen Records of Late Quaternary North American Sediments.* Dallas: Amer. Assoc. Stratigraphic Palynologists Foundation.

Cameron, C.C. 1975. *Some Peat Deposits in Southeastern Aroostook and Washington Counties, Maine.* USGS Bull. 1317-C.

Cameron, C.C., M.K. Mullen, C.A. Lepage, and W.A. Anderson. 1984. *Peat Resources of Maine,* 5 volumes. Maine Geol. Surv. Bull. 28–32

Clymo, R.S. 1983. Peat. In *Ecosystems of the World, v. 4A. Mires: Swamp, Bog, Fen and Moor*, ed. A.J.P. Gore, 159–224. Amsterdam: Elsevier.

———. 1984. The limits to peat bog growth. *Royal Soc. Lond., Phil. Trans. B.* 303: 605–654.

———. In press. Peat growth. In *Quaternary Landscapes,* ed. E.J.Cushing and L. Shane. Minneapolis: Univ. Minnesota Press.

Crum, H. 1984. *Sphagnopsida, Sphagnaceae. North American Flora, Ser. II, Part 11.* New York: N.Y. Botanical Garden

Crum, H., and L.E. Anderson. 1981. *Mosses of Eastern North America*; 2 volumes. New York: Columbia Univ. Press.

Davis, R.B. 1989a. Classification and distribution of freshwater peatlands in Maine (*draft*). Augusta: Critical Areas Program, Maine State Planning Office.

Davis, R.B. 1989b. Method and interim standards for quantitative evaluation of the ecological significance of Maine peatlands (*draft*). Augusta: Critical Areas Program, Maine State Planning Office.

Davis, R.B., and D.S. Anderson. In prep. a. The fens of Maine. Orono: Department of Botany and Plant Pathology, Univ. Maine.

———. In prep. b. The bogs of Maine. Orono: Department of Botany and Plant Pathology, Univ. Maine.

Davis, R.B., and F-S Hu. In prep. Origins and patterns of development of peatlands in Maine. Orono: Department of Botany and Plant Pathology, Univ. Maine.

Davis, R.B., and G.L. Jacobson Jr. 1985. Late glacial and early Holocene landscapes in northern New England and adjacent areas of Canada. *Quaternary Research* 23: 341–368.

Davis, R.B., G.L. Jacobson Jr., L.S. Widoff, and A. Zlotsky. 1983. Evaluation of Maine peatlands for their unique and exemplary qualities. Augusta: Maine Dept. Conservation.

Eurola, S., S. Hicks, and E. Kaakinen. 1984. Key to Finnish mire types. In *European Mires*. ed. P.D. Moore, 11–117. London: Academic Press.

Fernald, M.L. 1979. *Gray's Manual of Botany*, ed. 8 (corr. printing). New York: Amer. Book Co.

Foster, D.R., G.A. King, P.H. Glaser, and H.E. Wright Jr. 1983. Origin of string patterns in boreal peatlands. *Nature* (Lond.) 306: 256–258.

Foster, D.R., H.E. Wright Jr., M. Thelaus, and G.A. King. 1988. Bog development and landform dynamics in central Sweden and south-eastern Labrador, Canada. *J. Ecol.* 76: 1164–1185.

Glaser, P.H. 1987. *The Ecology of Patterned Boreal Peatlands of Northern Minnesota: A Community Profile*. U.S. Fish and Wildlife Serv., Biol. Rpt. 85(7.14).

Glaser, P.H., and J.A. Janssens. 1986. Raised bogs in eastern North America: Transitions in landforms and gross stratigraphy. *Can. J. Bot.* 64: 395–415.

Gore, A.J.P. 1983. Introduction. In *Ecosystems of the World, v. 4A. Mires: Swamp, Bog, Fen and Moor*, ed. A.J.P. Gore, 1–34. Amsterdam: Elsevier.

Gorham, E. 1955. On some factors affecting the chemical composition of Swedish fresh waters. *Geochim. Cosmochim. Acta* 7: 129–150.

Gorham, E. 1988. Canada's peatlands: Their importance for the global carbon cycle and possible effects of "greenhouse" warming. *Roy. Soc. Can., Trans., Ser. V.*, 3:21–23.

Gorham, E. 1991. Northern peatlands: Role in the carbon cycle and probable responses to climactic warming. *Ecological Applications* 1: 182–195.

Gorham, E., and J.A. Janssens. 1990. Concepts of fen and bog re-examined in relation to bryophyte cover and acidity of surface water. *Acta Societatis Botanicorum Poloniae.*

Gorham, E., S.J. Eisenreich, J. Ford, and M.V. Santelmann. 1985. The chemistry of bog waters. In *Chemical Processes in Lakes,* ed. W. Stumm, 339–363. New York: J. Wiley.

Gorham, E., J.K. Underwood, F. Martin, and J.G. Ogden. 1987. Natural and anthropogenic causes of lake acidification in Nova Scotia. *Nature* (Lond.) 324: 451–453.

Granlund, E. 1932. De Svenska hogmossarnas geologi. *Sver. Geol. Unders. Av. Uppsatser* 373: 1–193.

Hill, M.O. 1979. TWINSPAN—A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ithaca, NY: Cornell Univ.

Hu, Fengsheng. 1990. Holocene development of the north unit of Caribou Bog, central Maine, U.S.A. M.S. thesis, University of Maine, Orono.

Hu, Fengsheng, and R.B. Davis. In prep. Origin and development of Caribou Bog, Maine, U.S.A.

Ingram, H.A.P. 1983. Hydrology. In *Ecosystems of the Wworld, v. 4A. Mires: Swamp, Bog, Fen and Moor,* ed. A.J.P. Gore, 67–158. Amsterdam: Elsevier.

Jacobson, G.L., and R.B. Davis. 1988. The *real* forest primeval. *Habitat* 5: 26–29.

Kahl, J.S., S.A. Norton, R.K. McRae, T.A. Haines, and R.B. Davis. 1989. Influence of organic acidity on the chemistry of surface waters in Maine, U.S.A. *Water, Air, and Soil Pollution* (in press).

Küchler, A.W. 1967. *Vegetation Mapping.* New York: Ronald.

Lautzenheiser, R.E. 1972. Climate of Maine. *Climatography of the U.S.* No. 60–17, Washington, DC: U.S.D.C., N.O.A.A.

Lindsay, R.A., J. Riggall, and E.M. Bignal. 1983. Ombrogenous mires in Islay and Mull. Roy. Soc. Edinburgh, Proc. 83B: 341–371.

Moore, P.D. 1977. Stratigraphy and pollen analysis of Claish Moss, north-west Scotland; Significance for the origin of surface pools and forest history. *J. Ecol.* 65: 375–397.

Moore, P.D., and D.J. Bellamy. 1974. *Peatlands.* New York: Springer-Verlag.

Mueller-Dombois, D., and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. New York: Wiley.

National Wetland Research Group (NWWG). 1988. Wetlands of Canada. Environment Canada, Ottawa, Ecological Land Classification Series, No. 24, and Montreal: Polyscience Publ.

Osberg, P., A.M. Hussey II, and G.M. Boone. 1986. *Bedrock geological map of Maine*. Augusta: Maine Geol. Surv.

Osvald, H. 1935. A bog at Hartford, Michigan. *Ecol.* 16: 520–528.

Perkins, J. 1985. A palaeoecological study of the Smith Brook Deadwater peatland, Maine, U.S.A. Univ. Sheffield, U.K., Honors thesis.

Ratcliff, D.A. (Ed.). 1977. *A Nature Conservation Review*. 2 vols. Cambridge: Cambridge Univ. Press, (site descriptions for Claish Moss and Kentra Moss in vol. 2).

Ratcliff, D.A., and D. Walker. 1958. The Silver Flowe, Galloway, Scotland. *J. Ecol.* 46: 407–445.

Ruuhijärvi, R. 1960.Über die regionale Einteilung der nordfinnischen Moore. *Ann. Bot. Soc. "Vanamo"* 31 (1): 1–360.

———. 1983. The Finnish mire types and their regional distribution. In *Ecosystems of the World, v. 4B. Mires: Swamp, Bog, Fen and Moor, Regional Studies*, ed. A.J.P. Gore, 47–67. Amsterdam: Elsevier.

Rydin, H., and R.S. Clymo. 1989. Transport of carbon and phosphorus compounds about *Sphagnum*. *Roy. Soc. Lond., Proc.* B 237: 63–84.

Shotyk, W. 1988. Review of the inorganic geochemistry of peats and peatland waters. *Earth-Sci. Rev.* 25: 95–176.

Sjörs, H. 1950. On the relation between vegetation and electrolytes in north Swedish mire waters. *Oikos* 2: 241-258.

———. 1983. Mires of Sweden. In *Ecosystems of the World, v. 4B. Mires: Swamp, Bog, Fen and Moor, Regional Studies*, ed. A.J.P. Gore, 69-94. Amsterdam: Elsevier.

Sorenson, E.R. 1986. The ecology and distribution of ribbed fens in Maine. Augusta: Maine State Planning Office, Planning Rpt. 81.

Sullivan, T.J., C.T. Driscoll, S.A. Gherini, R.K. Munson, R.B. Cook, D.F. Charles, and C.P. Yatsko. 1989. Influence of aqueous aluminium and organic acids on measurement of acid neutralizing capacity in surface waters. *Nature* (Lond.) 338: 408–410

Tallis, J.H. 1983. Changes in wetland communities. In *Ecosystems of the World, v. 4B. Mires: Swamp, Bog, Fen and Moor, Regional Studies*, ed. A.J.P. Gore, 311–347. Amsterdam: Elsevier.

Tansley, A.G. 1949. *The British Islands and Their Vegetation*, (2 vols.). Cambridge: Cambridge Univ. Press.

Taylor, J.A. 1983. The peatlands of Great Britain and Ireland. In *Ecosystems of the World, v. 4B. Mires: Swamp, Bog, Fen and Moor, Regional Studies*, ed. A.J.P. Gore, 1–46. Amsterdam: Elsevier.

ter Braak, C.J.F. 1986. Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecol.* 67: 1167–1179.

———. 1987. CANOCO—A FORTRAN program for CANOnical Community Ordination by [partial]-[detrended] [canonical] correspondence analysis, principal components analysis and redundancy analysis. Wageningen, Neth.: TNO Institute of Applied Computer Science.

Thompson, W.B., and H.W. Borns Jr. 1985. Surficial geologic map of Maine. Augusta: Maine Geol. Surv.

Tolonen, K. 1967. Über die Entwicklung der Moore in finnischer Nordkarelien. *Ann. Bot. Fenn.* 4: 219–416.

Tolonen, K., R.B. Davis, and L. Widoff. 1988. Peat accumulation rates in selected Maine peat deposits. Maine Geol. Surv. Bull. 33.

United States Department of Commerce. 1968. Climate atlas of the United States. Washington, DC: U.S.D.C.

Urban, N.R., S.J. Eisenreich, and E. Gorham. 1987. Proton cycling in bogs: Geographic variation in northeastern North America. In *Effects of Atmospheric Pollutants on Forests, Wetlands and Agricultural Ecosystems*, ed. T.C. Hutchinson and K.M. Meema, 577–598. Berlin: Springer-Verlag.

Wells, E.D., and F.C. Pollett. 1983. Peatlands. In *Biogeography and Ecology of the Island of Newfoundland*, ed. G.R. South, 207–265. The Hague, Neth.: Dr. W. Junk Publ.,

Widoff, L.S., and J. Ruffing. 1984. Ecological investigations of 15 selected raised bogs in Maine, summer 1984. Augusta: Maine Office Energy Resources.

Worley, I.A. 1980. Botanical and ecological aspects of coastal raised peatlands in Maine. Augusta: Maine State Planning Office, Planning Rpt. 69.

———. 1981a. 1000 Acre Heath, T3 R1 NBPP, Maine—A report on significant peatland features for The Nature Conservancey. Brunswick, ME: Maine Chapter of the Nature Conservancy.

———. 1981b. Maine peatlands, their abundance, ecology, and relevance to the Critical Areas Program. Augusta: Maine State Planning Office, Planning Rpt. 73.

APPENDIX 1

Plant Taxa and Their Abundance in Maine's Eccentric Bog Complexes

For the 15 complexes sampled in the field in 1987. The first column is the number of relevés, out of a total of 85, in which the taxon was recorded. The second column is the number of complexes where the taxon was recorded. The third column is the mean percentage cover of the taxon in the 85 relevés. Conventions followed for taxonomic specificity are explained in the text.

	Number of relevés	Number of peatlands	Mean percent cover
Chamaedaphne calyculata	70	15	19.4
Kalmia angustifolia	65	15	8.2
Sphagnum capillifolium var. tenellum	59	15	21.8
Vaccinium oxycoccos	59	15	2.3
Picea mariana	58	15	12.2
Sphagnum magellanicum	57	15	5.2
Ledum groenlandicum	51	15	5.5
Kalmia polifolia	46	15	0.4
Sarracenia purpurea	44	15	0.4
Sphagnum recurvum agg.	42	15	9.1
Sphagnum fuscum	40	15	6.7
Andromeda glaucophylla	38	15	2.0
Eriophorum spissum	37	15	3.5
Cladina rangiferina	37	14	2.3
Pleurozium schreberi	32	14	1.3
Dicranum spp. (unspecified)	32	14	0.5
Gaultheria hispidula	31	15	0.7
Drosera rotundifolia	31	15	0.5
Sphagnum capillifolium nom. var.	30	15	0.7
Carex trisperma	28	15	5.8
Eriophorum virginicum	28	15	2.1
Rhododendron canadense	26	15	7.1
Nemopanthus mucronata	24	14	3.2
Vaccinium myrtilloides	23	15	1.4
Bazzania trilobata	20	14	1.4
Ptilidium ciliare	20	14	0.6
Acer rubrum	19	15	0.8
Larix laricina	18	15	1.3
Viburnum cassinoides	18	13	1.5
Mylia anomala	15	9	0.1
Alnus rugosa	13	12	2.7
Rhynchospora alba	12	15	3.0
Gaylussacia baccata	12	14	1.5
Vaccinium corymbosum	12	11	0.3
Aronia floribunda	11	13	0.4
Cornus canadensis	11	13	0.1
Polytrichum strictum	11	7	0.1
Smilacina trifolia	10	14	0.7
Gaultheria procumbens	10	10	0.1
Dicranum undulatum	10	6	0.4
Coptis groenlandica	9	12	0.2
Thuja occidentalis	8	13	0.4
Myrica gale	8	7	0.6
Osmunda cinnamomea	7	13	0.6
Cladopodiella fluitans	7	10	0.9
Cladonia cristatella	7	6	0.1
Thuidium delicatulum	6	9	0.2
Maianthemum canadense	6	8	0.1
Cladina stellaris	5	12	0.0
Abies balsamea	5	9	0.7

Cont

	Number of relevés	Number of peatlands	Mean percent cover
Ilex verticillata	5	9	0.6
Sphagnum girgensohnii	5	8	1.0
Carex stricta	5	6	0.2
Plagiomnium ellipticum	5	6	0.2
Sphagnum cuspidatum	4	13	2.2
Utricularia cornuta	4	12	0.8
Carex pauciflora	4	9	0.5
Rubus hispidus	4	9	0.0
Onoclea sensibilis	4	8	0.4
Aronia melanocarpa	4	6	0.1
Iris versicolor	3	8	0.0
Calla palustris	3	7	0.2
Carex oligosperma	3	6	2.8
Viola spp. (unspecified)	3	6	0.0
Fraxinus nigra	3	5	0.3
Trientalis borealis	3	5	0.0
Cephalozia spp.	3	3	0.0
Cladonia gracilis	3	3	0.0
Eriophorum tenellum	2	7	0.2
Hypericum virginicum	2	7	0.0
Calamagrostis canadensis	2	6	0.2
Spiraea latifolia	2	6	0.2
Lycopus spp. (unspecified)	2	6	0.0
Scheuchzeria palustris	2	4	0.2
Calliergon stramineum	2	4	0.0
Osmunda regalis	2	4	0.0
Cladonia spp. (unspecified)	2	3	0.0
Sphagnum teres	2	3	0.0
Dicranum scoparium	2	2	0.0
Hypnum curvifolium	2	1	0.0
Pinus strobus	1	12	0.0
Carex paupercula	1	8	0.0
Betula lutea	1	7	0.0
Drosera intermedia	1	7	0.0
Eriophorum angustifolium	1	6	0.2
Aralia nudicaulis	1	6	0.0
Oxalis montana	1	6	0.0
Betula populifolia	1	5	0.0
Carex canescens	1	5	0.0
Lysimachia terrestris	1	4	0.0
Picea rubens	1	3	0.1
Dalibarda repens	1	3	0.0
Dryopteris cristata	1	3	0.0
Osmunda claytoniana	1	3	0.0
Pyrus americana	1	3	0.0
Rhytidiadelphus triquetrus	1	3	0.0
Rosa nitida	1	3	0.0
Sphagnum subsecundum s.l.	1	3	0.0
Spiraea tomentosa	1	3	0.0
Thelypteris palustris	1	3	0.0
Tsuga canadensis	1	3	0.0
Sphagnum papillosum	1	2	0.2
Amelanchier spp. (unspecified)	1	2	0.0
Arceuthobium pusillum	1	2	0.0
Carex spp. (unspecified)	1	2	0.0

Cont

	Number of relevés	Number of peatlands	Mean percent cover
Drepanocladus fluitans	1	2	0.0
Equisetum fluviatile	1	2	0.0
Glyceria spp. (unspecified)	1	2	0.0
Lonicera villosa	1	2	0.0
Mitchella repens	1	2	0.0
Polytrichum commune	1	2	0.0
Potentilla palustris	1	2	0.0
Rhamnus alnifolia	1	2	0.0
Scirpus rubrotinctus	1	2	0.0
Sphagnum capillifolium var. tenerum	1	2	0.0
Viburnum recognitum	1	2	0.0
Sphagnum imbricatum	1	1	0.7
Unknown Cyperaceae 52	1	1	0.4
Unknown Gramineae 64	1	1	0.2
Unknown Cyperaceae 63	1	1	0.2
Acer spicatum	1	1	0.0
Aulacomnium palustre	1	1	0.0
Cephalozia connivens v. compacta	1	1	0.0
Dicranum ontariense	1	1	0.0
Dicranum polysetum	1	1	0.0
Ditrichtum pusillum	1	1	0.0
Dryopteris noveboracensis	1	1	0.0
Eleocharis cf. palustris	1	1	0.0
Hylocomium splendens	1	1	0.0
Lonicera canadensis	1	1	0.0
Lophozia cf. attenuata	1	1	0.0
Pohlia nutans	1	1	0.0
Polygonum cf. amphibium	1	1	0.0
Pyrola secunda	1	1	0.0
Pyrola sp.	1	1	0.0
Salix sp.	1	1	0.0
Sphagnum sp.	1	1	0.0
Tilia americana	1	1	0.0
Splachnum ampullaceum	1	1	0.0
Nuphar variegatum	0	11	0.0
Carex intumescens	0	6	0.0
Sphagnum wulfianum	0	6	0.0
Vaccinium macrocarpon	0	6	0.0
Carex interior	0	5	0.0
Carex lasiocarpa	0	5	0.0
Fragaria virginiana	0	5	0.0
Vaccinium angustifolium	0	5	0.0
Clintonia borealis	0	4	0.0
Habenaria blephariglottis	0	4	0.0
Acer pensylvanicum	0	3	0.0
Arisaema stewardsonii	0	3	0.0
Aster spp.	0	3	0.0
Betula papyrifera	0	3	0.0
Calopogon pulchellus	0	3	0.0
Carex crinita	0	3	0.0
Corylus cornuta	0	3	0.0
Equisetum sylvaticum	0	3	0.0
Galium spp.	0	3	0.0
Linnaea borealis	0	3	0.0

Cont

	Number of relevés	Number of peatlands	Mean percent cover
Nymphaea odorata	0	3	0.0
Carex limosa	0	2	0.0
Carex stipata	0	2	0.0
Cladina mitis	0	2	0.0
Cornus amomum	0	2	0.0
Dryopteris disjuncta	0	2	0.0
Dulichium arundinaceum	0	2	0.0
Menyanthes trifoliata	0	2	0.0
Odontoschizma spp.	0	2	0.0
Polytrichum spp.	0	2	0.0
Pontederia cordata	0	2	0.0
Ptilium crista-castrensis	0	2	0.0
Scirpus spp.	0	2	0.0
Sphagnum russowii	0	2	0.0
Anthyrium filix-femina	0	1	0.0
Arabis sp.	0	1	0.0
Arethusa bulbosa	0	1	0.0
Aster cf. nemoralis	0	1	0.0
Aster nemoralis	0	1	0.0
Aster umbellatus	0	1	0.0
Brassica sp.	0	1	0.0
Bryhnia novae-angliae	0	1	0.0
Callicladium haldanianum	0	1	0.0
Calypogeia sp.	0	1	0.0
Campanula aparinoides	0	1	0.0
Carex brunnescens	0	1	0.0
Carex disperma	0	1	0.0
Carex exilis	0	1	0.0
Carex folliculata	0	1	0.0
Carex lacustris	0	1	0.0
Carex michauxiana	0	1	0.0
Carex paleocea	0	1	0.0
Carex paupercula cf. var. brevisquama	0	1	0.0
Carex pseudo-cyperus	0	1	0.0
Carex rostrata	0	1	0.0
Carex rostrata var. utriculata	0	1	0.0
Carex subimpressa	0	1	0.0
Cicuta sp.	0	1	0.0
Circaea alpina	0	1	0.0
Cladonia pyxidata	0	1	0.0
Climacium dendroides	0	1	0.0
Drepanocladus exannulatus	0	1	0.0
Dryopteris intermedia	0	1	0.0
Dryopteris phegopteris	0	1	0.0
Dryopteris spinulosa	0	1	0.0
Eriophorum viridi-carinatum	0	1	0.0
Galium tinctorium	0	1	0.0
Glyceria borealis	0	1	0.0
Glyceria cf. laxa	0	1	0.0
Glyceria cf. septentrionalis	0	1	0.0
Habenaria sp.	0	1	0.0
Impatiens sp.	0	1	0.0
Juncus effusus	0	1	0.0
Juncus sp.	0	1	0.0
Leucobryum glaucum	0	1	0.0
Lycopus virginicus	0	1	0.0

Cont

	Number of relevés	Number of peatlands	Mean percent cover
Lysimachia sp.	0	1	0.0
Lythrum sp.	0	1	0.0
Mitella nuda	0	1	0.0
Monotropa uniflora	0	1	0.0
Oxalis acetosella	0	1	0.0
Phleum sp.	0	1	0.0
Picea glauca	0	1	0.0
Pogonia ophioglossoides	0	1	0.0
Polygonum sp.	0	1	0.0
Potamogeton sp.	0	1	0.0
Prunus sp.	0	1	0.0
Pyrola elliptica	0	1	0.0
Quercus rubra	0	1	0.0
Rhus radicans	0	1	0.0
Rubus sp.	0	1	0.0
Rumex cf. crispus	0	1	0.0
Sagittaria latifolia	0	1	0.0
Sagittaria sp.	0	1	0.0
Salix cf. gracilis	0	1	0.0
Salix pedicellaris	0	1	0.0
Salix setiolaris	0	1	0.0
Scapania sp.	0	1	0.0
Scirpus cespitosus	0	1	0.0
Scirpus cf. pedicellatus	0	1	0.0
Scirpus cyperinus	0	1	0.0
Scirpus pedicellatus	0	1	0.0
Scutellaria lateriflora	0	1	0.0
Scutellaria sp.	0	1	0.0
Sium suave	0	1	0.0
Sphagnum centrale	0	1	0.0
Sphagnum fimbriatum	0	1	0.0
Sphagnum squarrosum	0	1	0.0
Thalictrum sp.	0	1	0.0
Trillium undulatum	0	1	0.0
Typha latifolia	0	1	0.0
Ulmus americana	0	1	0.0
Unknown Cyperaceae 47	0	1	0.0
Unknown Labiatae	0	1	0.0
Uvularia sp.	0	1	0.0
cf. Rhizomnium magnifolium	0	1	0.0

APPENDIX 2

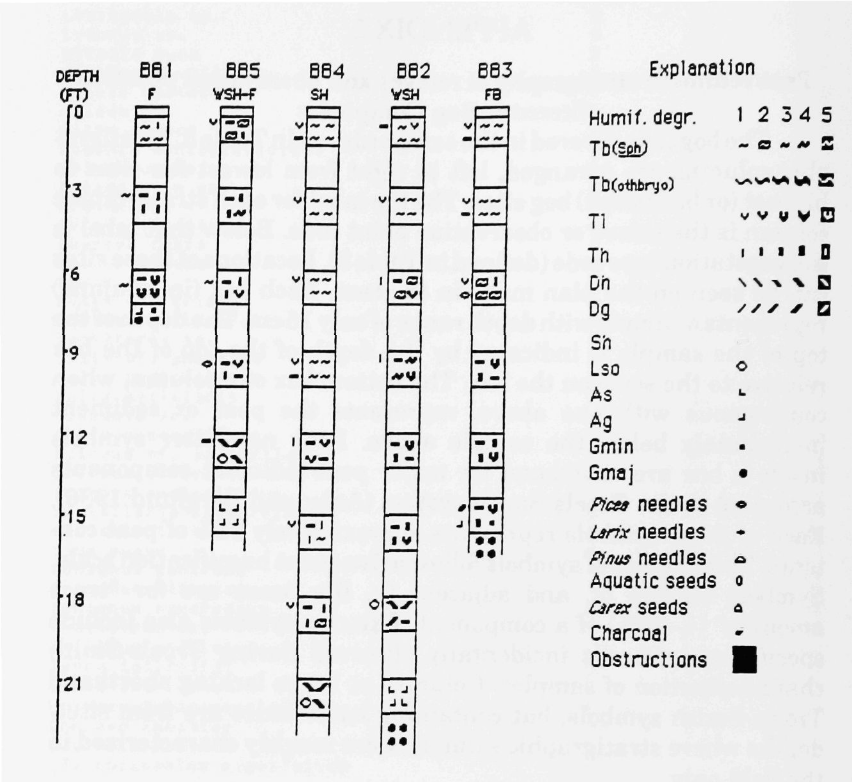
Peat/sediment stratigraphy at relevés and observation points at Eccentric Bog Complexes

The bogs are covered in the same order as in Table 3. Stratigraphic columns are arranged, left to right from lowest fen sites to highest (or backslope) bog sites. The top label for each stratigraphic column is the relevé or observation point code. Below that label is the vegetation type code (defined in Table 8). Locations of these sites can be seen on the plan maps in the text. Each box (in columns) represents a sample with depth range of only 15 cm. The depth of the top of the sample is indicated by the depth of the top of the box relative to the scale on the left. The bottom box of a column, when continguous with one above, represents the peat or sediment immediately below the sample above. Four non-letter symbols inside a box are shorthand for major peat/sediment components according to the Troels-Smith system (Aaby and Berglund 1986). Each of these symbols represents approximately 25% of peat contents. Thicknesses of symbols follow a five-point humification scale. Symbols outside of, and adjacent to, the boxes are for "trace amounts" (<~10%) of a component. Exterior symbols also include specific macrofossils incidentally observed during Troels-Smith characterization of samples. Columns or boxes lacking shorthand Troels-Smith symbols, but containing letter codes are from sites/depths where stratigraphic samples were roughly characterized in the field only.

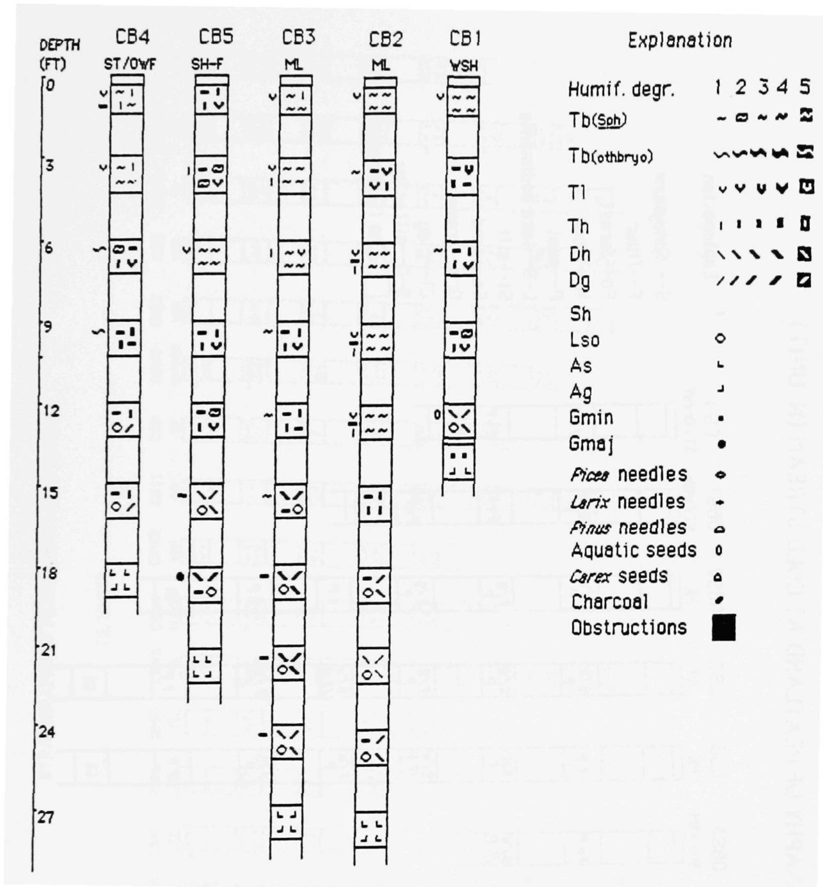
Tb(*Sph*) = turfa bryophytica (*Sphagnum*)
Tb(othbryo) = turfa bryophytica (non-*Sphagnum* bryophyte)
Tl = turfa lignosa
Th = turfa herbacea
Dh = detritus herbosus
Dg = detritus granosus
Sh = substantia humosa
Lso = limus siliceus organogenes
As = argilla steatodes
Ag = argilla granosa
Gmin = grana minora
Gmaj = grana majora

Turfa = *in situ* plant remains; detritus = transported (usually in water) plant remains; limus = aquatic sediment; argilla = mineral clays and silts; grana = mineral sands and gravels; substantia humosa = homogenous organic substance, usually largely turfa-derived but not visually identifiable to turfa type, and may derive in part from certain aquatic or soil components.

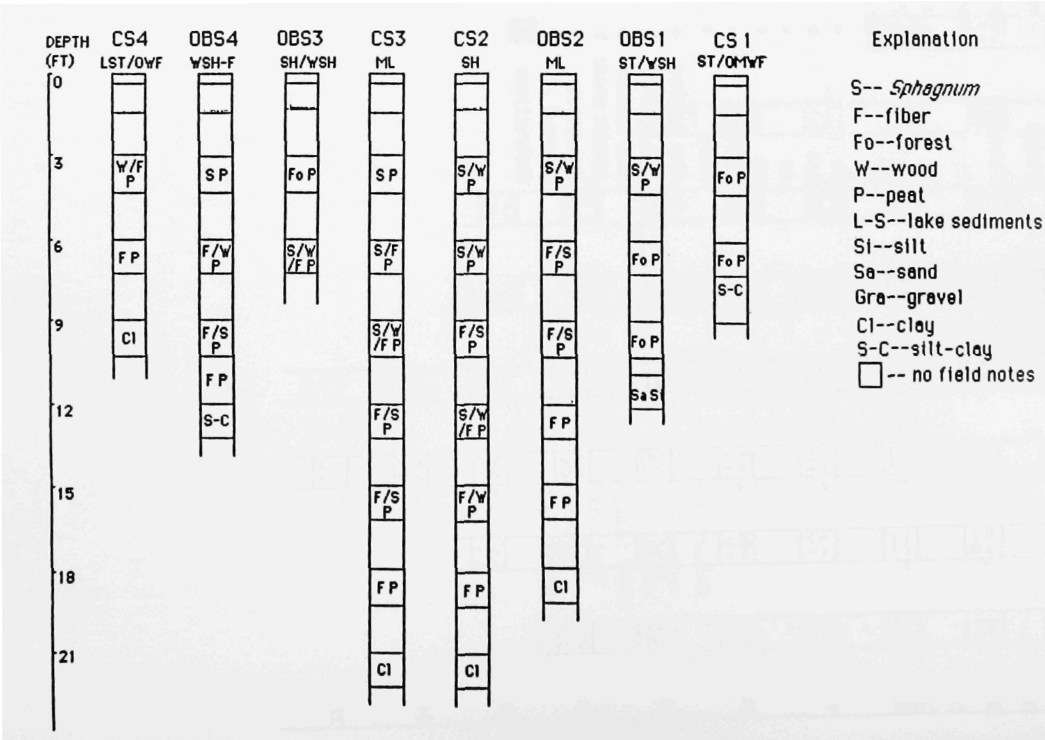
STRATIGRAPHY OF BIG BOG



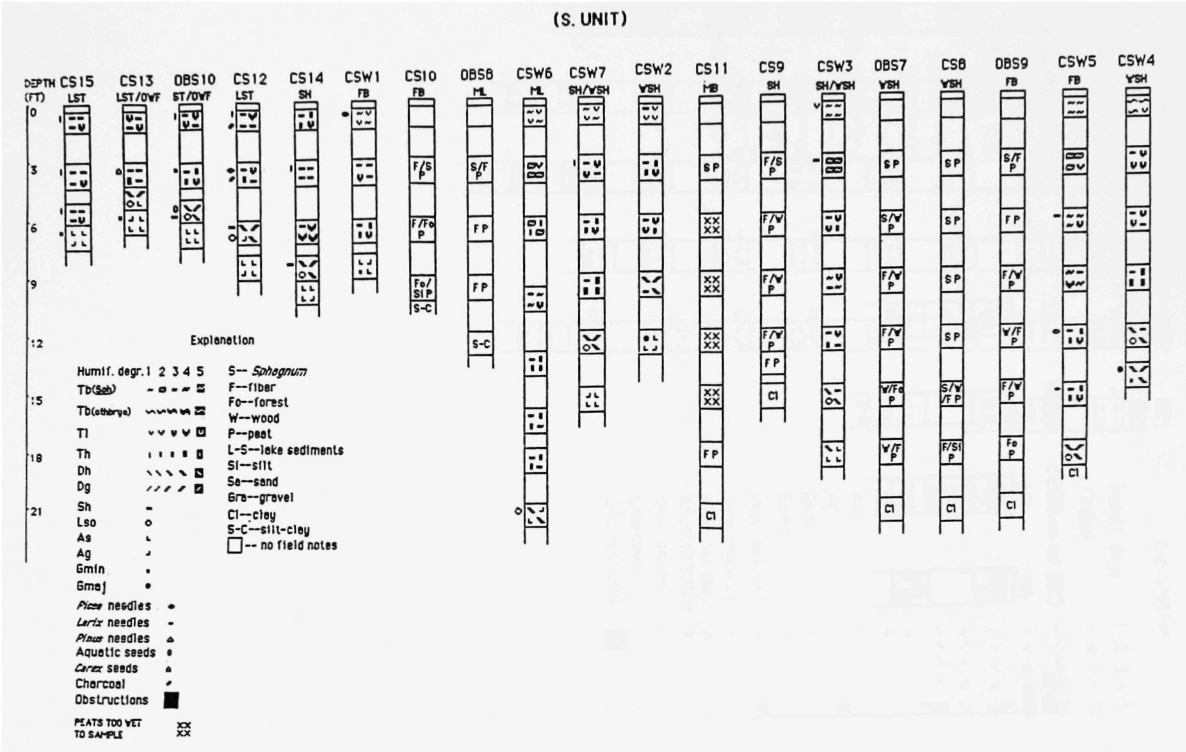
STRATIGRAPHY OF COFFIN BOG



STRATIGRAPHY OF PEATLAND AT COLD STREAM (N. UNIT)

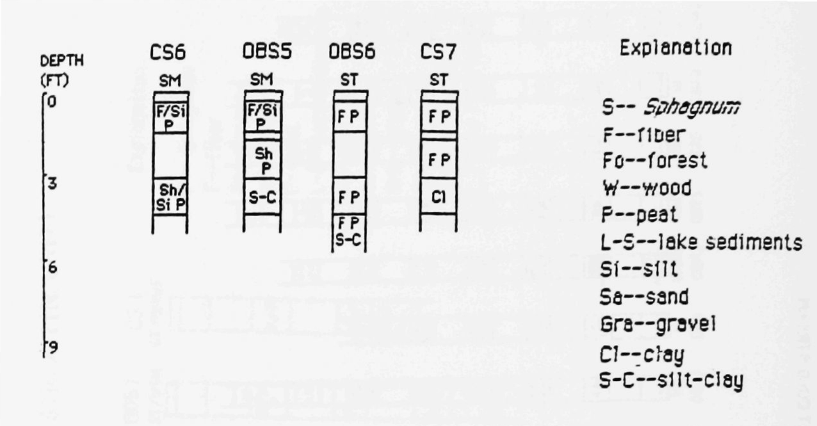


STRATIGRAPHY OF PEATLAND AT COLD STREAM

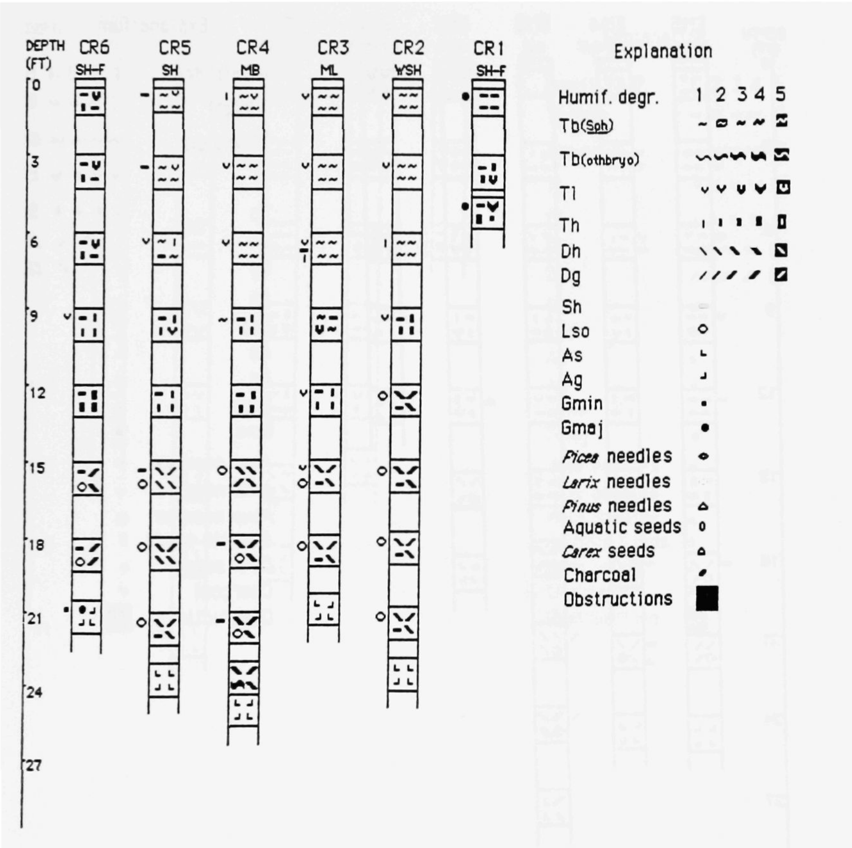


STRATIGRAPHY OF PEATLAND AT COLD STREAM

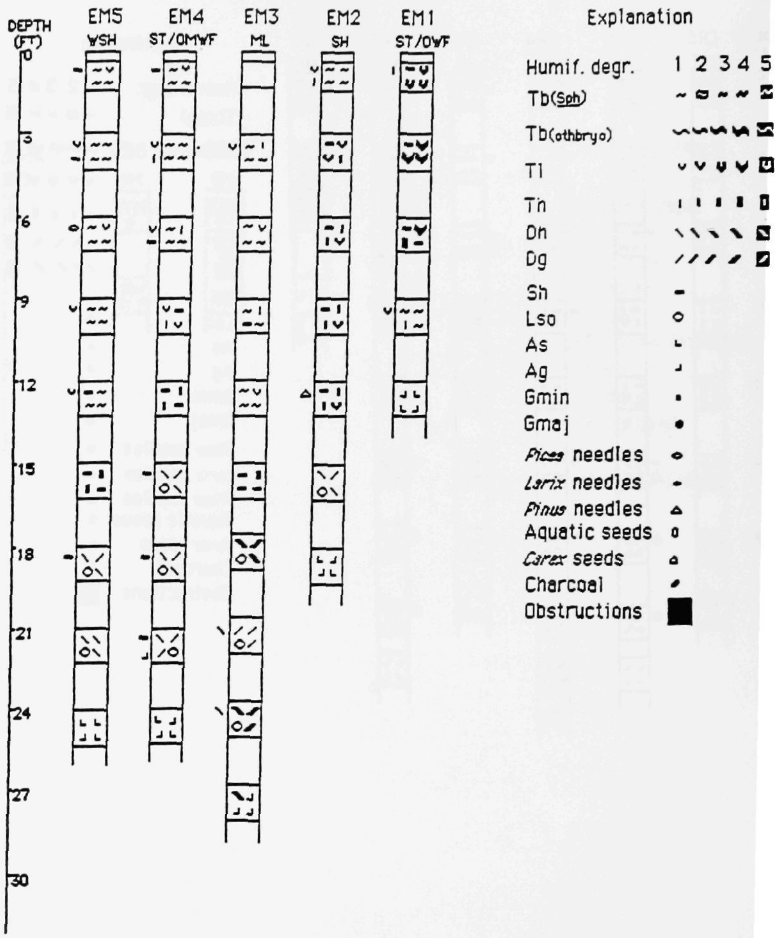
(UNIT S. OF PASSADUMKEAG RIVER)



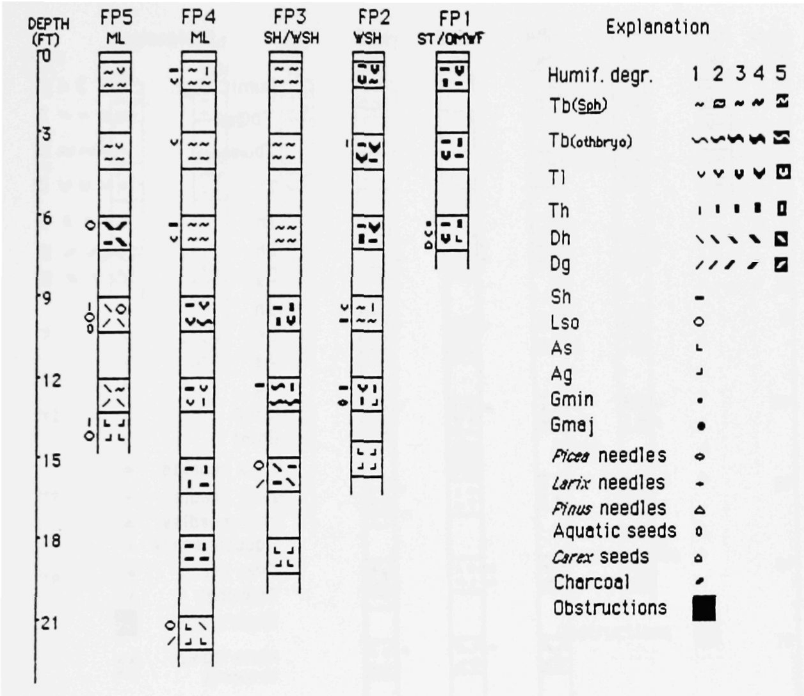
STRATIGRAPHY OF PEATLAND AT CROSSUNTIC STREAM



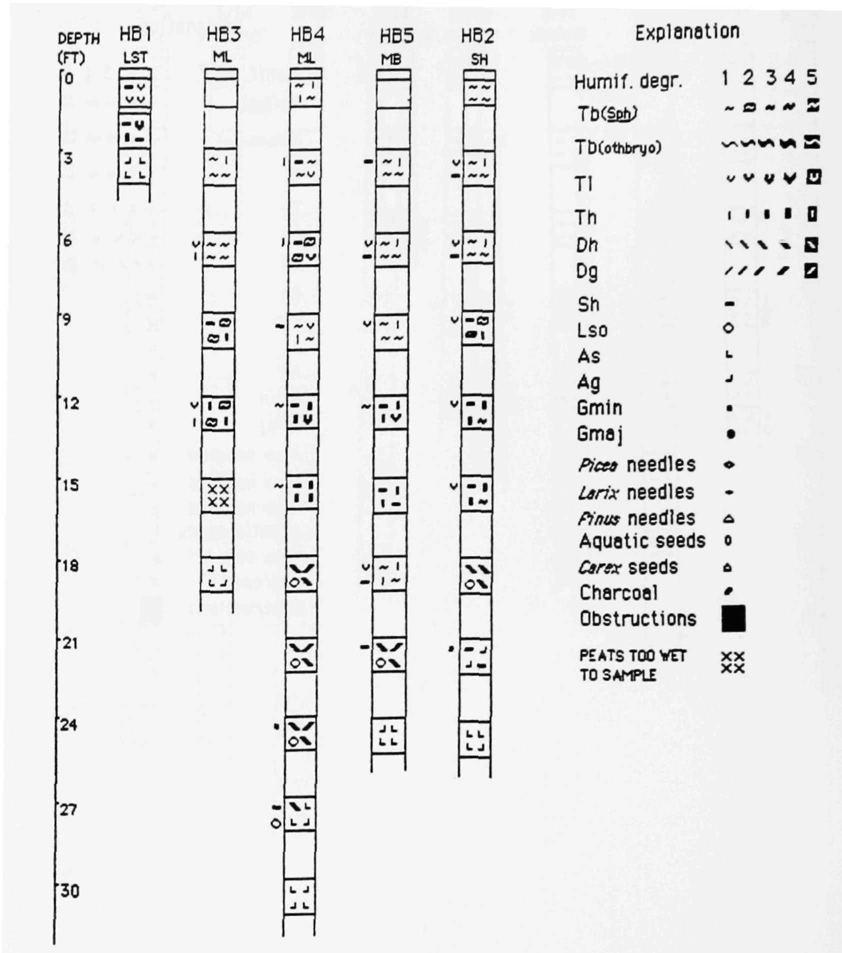
STRATIGRAPHY OF PEATLAND AT ELEVENMILE LAKE



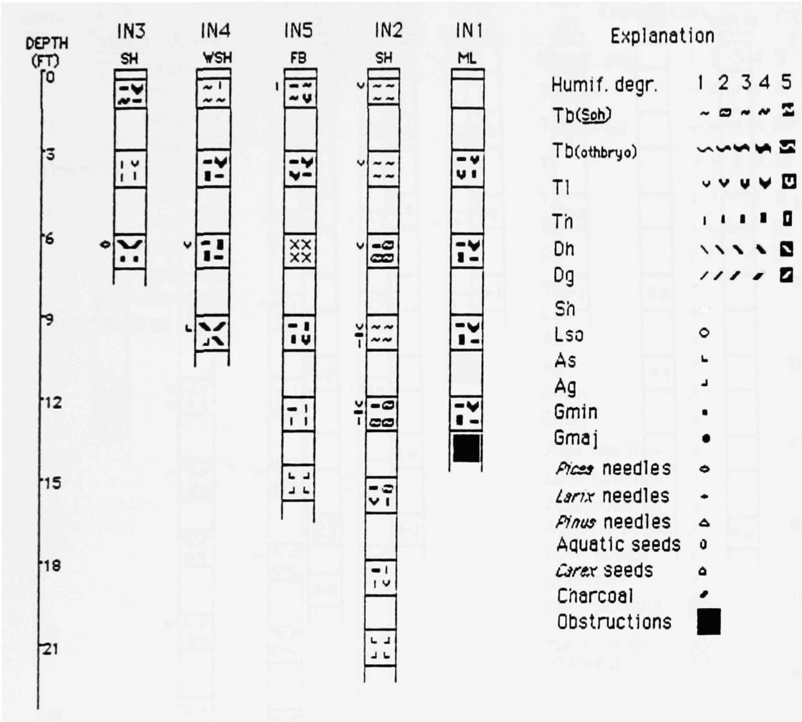
STRATIGRAPHY OF PEATLANDS AT FLINN POND



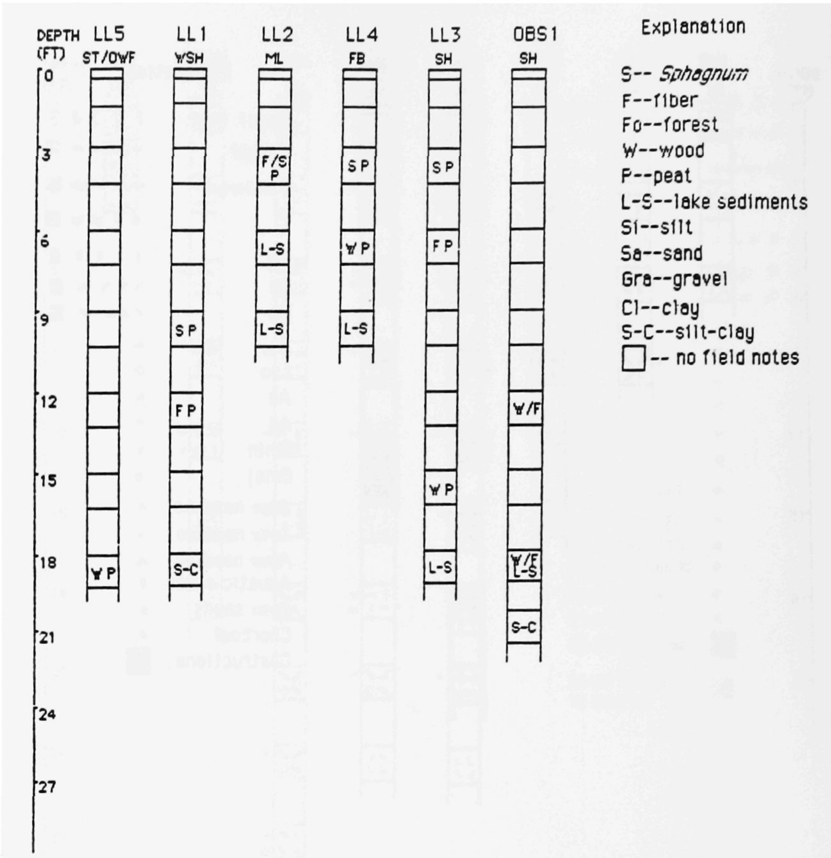
STRATIGRAPHY OF HATHAM BOG



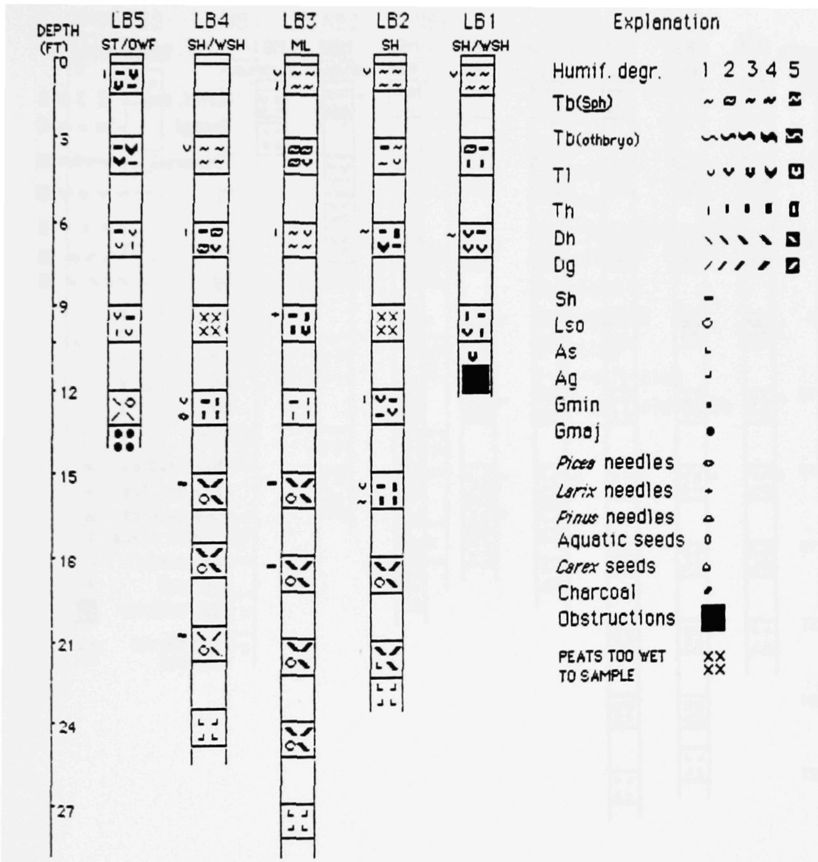
STRATIGRAPHY OF INMAN BOG



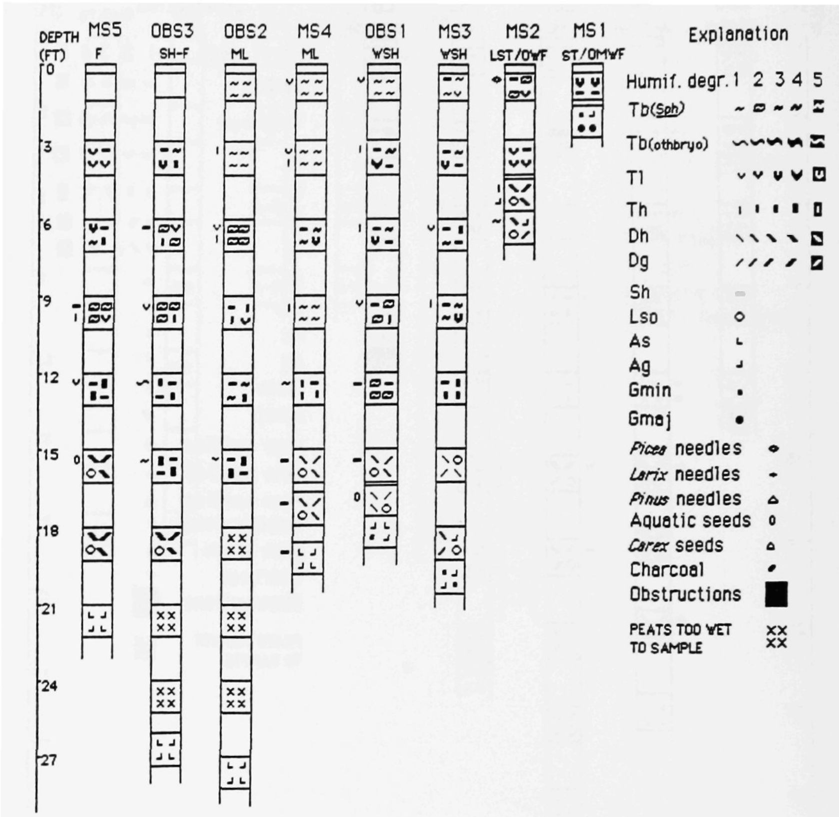
STRATIGRAPHY OF PEATLAND AT LAMBERT LAKE



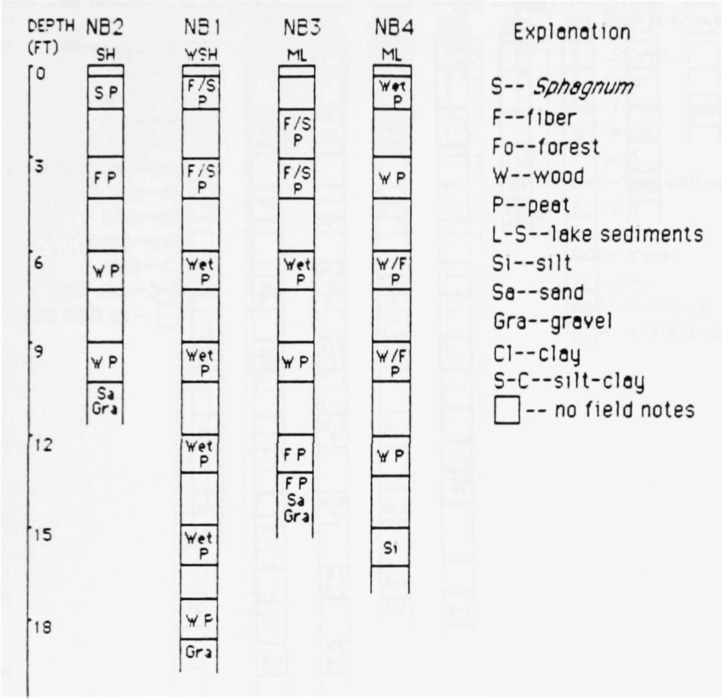
STRATIGRAPHY OF PEATLAND AT LINDSEY BROOK



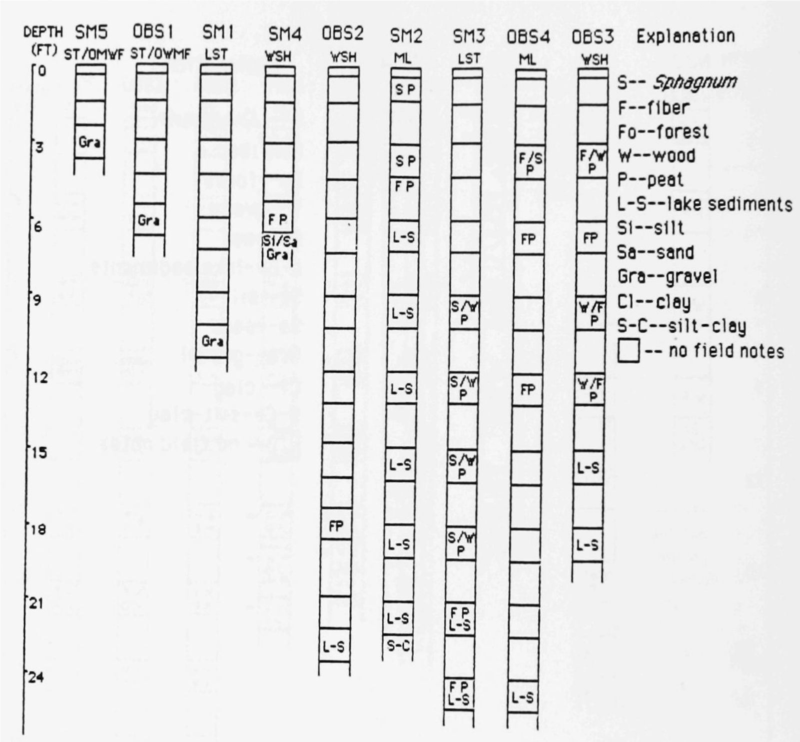
STRATIGRAPHY OF PEATLAND AT MACWAHOC STREAM



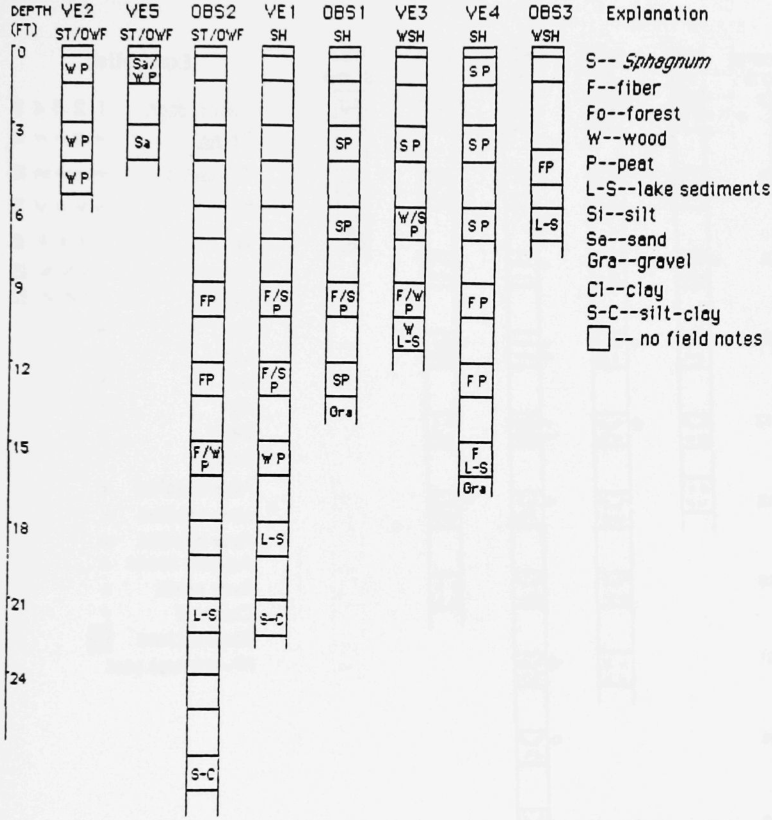
STRATIGRAPHY OF PEATLAND AT NOLLESEMIC STREAM



STRATIGRAPHY OF PEATLAND AT STETSON MOUNTAIN



StRATIGRAPHY OF PEATLAND AT VANCEBORO



STRATIGRAPHY OF WADLEIGH BOG