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Like nothing uphill : ecology and conservation of a northern Minnesota peat bog

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LIKE NOTHING UPHILL: ECOLOGY AND CONSERVATION OF A NORTHERN MINNESOTA PEAT BOG

by

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Preface

A professional paper allows the writer a wide degree of artistic and expressive freedom. This characteristic, more than any other, appeals to my sense of what environmentalism, conservation, and esthetic appreciation is all about. Our concern for ecosystems and species stems from our liking them. The facts that bombard us daily become real only when our consciousness is lifted to a higher level by our personal involvement.

I like bogs. I thoroughly enjoy stomping through peatlands, taking the soft surface and waterlogged vegetation in stride. I also know something about the ecological processes of bogs. From this vantage point, I see clearly that liking bogs is much more motivating than simply knowing about bogs. Unfortunately for the writer who is trying to call readers to action, getting the facts across is much easier than painting the subjective, emotional picture of "like."

I have attempted to do just that, however. Along with an extensive literature review, I interject portions of my journal into the following paper. The journal, written in a different font type, oftentimes closes a section with a purely subjective view of a particular peat bog. The section headings themselves do not follow standard convention but are excepts of literature. The text softens its numerous scientific references with a more breezy, less staid style than that found in conventional theses. In a nutshell, the paper aims to enlighten, and excite, the reader about peat bogs.

My own bog mania was not nurtured in a vacuum. I owe thanks and gratitude to a wide variety of people who fanned the fires of enthusiasm

when I was a child, and later when I studied bogs as a graduate student. Especially, I appreciate the interest and guidance of Tom Roy, Charles Miller, and Thomas Nimlos. Special thanks to Thomas Jones, Paul Monson, Don Christian, and Tom Malterer for their help with field work, plant identification, and technical guidance. Lastly, I must recognize the undying support of my family and friends who encouraged me, with only limited jesting, while I endeavored to write this, the dairy of a swamp thing.

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BOG: *n*; soft, waterlogged ground; traces to several meanings in the English language, all of which refer to the insecure footing of peatlands and danger of being mired or "bogged" down (Curtis 1959, Morris 1976).

In the temperate climates of North America, Europe, and Asia, bogs alternately fascinate and frustrate the people who live alongside them. Although a beautiful, mysterious addition to the upland landscape, bogs are a contrary resident. Those who chance to gaze into a bog usually do so with indifference.

Most bogs are found north of the 44th parallel (Reader 1978b). The cool, wet climate of Minnesota, with a mean annual temperature of 36-39° F and an average yearly precipitation of 21-30 inches, is favorable for the development of bogs (Malterer 1980); Minnesota is second only to Alaska in peatland acreage (Foth and Schafer 1980). This status as the peatland state also earns Minnesota recognition in such dubious areas as mosquito production. Not surprisingly, until the early 1900's, most of the attention paid to bogs was directed toward their reclamation.

The drainage of wetlands has historically proven to be disastrous, however. Phenomenally large areas of wetlands no longer exist or are nearly extirpated. The list reads like a casualty roster: ninety percent of Nebraska's Rainwater Basin wetlands drained for agriculture (Baldwin 1987), 95 percent of San Francisco Bay's tidal marshes destroyed in the interests of urbanization, the entire Great Kankakee Swamp of Illinois and Indiana channelled into a ditch for the creation of cropland and pasture (Mitsch and Gosselink 1986).

What justifies such large scale reclamation? Few would argue that wetlands are barriers to development. People need to eat, need places to live, need space to expand. Wetlands often interfere with our plans for improvement and growth. Unfortunately, our ravenous appetite for land has turned on us. Only recently have we understood the crucial roles wetlands play in flood control, water supply, and wildlife production, and the enormous costs associated with these functions (Pearson 1985). The mistakes of the past are not easily rectified in the present.

Fortunately, our attention shifted toward studying and examining wetlands as important ecosystems. As one of the most ubiquitous wetland types, peatlands benefitted from research worldwide. Inquiry uncovered the ecological processes that set bogs apart from other wetland ecosystems. Bogs form when a cool, wet climate retards evaporation for thousands of years. Man-made wetlands have met with some success in coastal and riverine systems, but only time builds a peat bog. For all intents and purposes, peat bogs are nonrenewable. The mistakes we make in peat bog reclamation today are not reversible.

Despite all the research and scrutiny into bog ecology, peatlands continue to be drained at an alarming rate. In Minnesota alone, over 2,000 acres of peatlands are drained each year for agriculture (Kivinen 1980). This does not take into account the acreage that is reclaimed for purposes other than cropland, making this trend particularly threatening. We still do not understand all the chemical, hydrological, and biological relationships in bogs, and our haste to create a more desirable landscape may beleaguer us later, as it now does in the prairie pothole region, river deltas, and coastal cities. Luckily, with effort and understanding, history does not have to repeat itself.

The scientific and ecological communities perceive the importance of maintaining the integrity of peatlands, however this knowledge rarely trickles down to the people who make land use decisions regarding bogs. This sparse, inadequate information allows landowners to look upon their bogs as hostile, unapproachable, and estranged from their daily lives. The information is readily available, but the volume of literature overwhelms even students of bog ecology. Such double jeopardy leaves peatlands vulnerable to apathy: They are too inaccessible in the field and too encumbered in the literature. Fortunately, bogs have charisma.

The mist that settles into bogs on autumn nights lifts every morning to reveal a complex, fascinating wetland. The fog of indifference also lifts when bogs are experienced and explained. While the knowledge can be gained from the literature, the spirit only comes from the center of the bog. Admittedly, bogs are not user-friendly. They earned the name "bog" with good reason. Not everyone will emerge from a bog, boots shining wet, and look back with admiration and satisfaction. Fair enough. But because the integrity, and perhaps even the future, of the Minnesota landscape depends on informed, concerned use of peatlands, every landowner needs to look back on a bog, boots shining wet, and nod with understanding.

Land of 10,000 lakes, 30,000 bogs

Minnesota contains over six million acres of varied, diverse peatlands (Foth and Schafer 1980). These peatlands can be loosely separated into two types: bogs and fens. Bogs, or ombrotrophic peatlands, receive most of their nutrient inputs through rainfall, making them exceedingly nutrient-poor. Fens, or minerotrophic peatlands, on the other hand, receive mineral inputs and support richer vegetation. These two distinct wetlands characterize much of the state's landscape.

The majority of Minnesota's peat lies in the northern counties of Lake, St. Louis, Koochiching, Lake of the Woods, Itasca, Beltrami, Carlton, and Aitkin (Minnesota Department of Natural Resources (MN DNR) 1978). Along with its extensive peat deposits, Minnesota enjoys a long and respected history as a major center of peat research. Within the last thirteen years, this research was expedited by the Minnesota Department of Natural Resources (DNR) peat program. While it was in effect, the program compiled the largest peat inventory in the country and recommended policies for regulation of the state's peat resources (MN DNR 1987).

The State owns most of the peatlands in Minnesota (Malterer 1980). Because the peat program's emphasis focused on state peatlands, privately owned bogs and fens were all but forgotten in the flurry of research. Conservation measures proposed by the DNR also concentrated on state-owned peatlands. While the state was spending millions of dollars on peat research and conservation measures, bog owners were ditching and filling in lowlands. Privately-owned bogs simply cannot be discounted in the haste to recognize the importance of Minnesota's peat resource. Private landowners, unlike the state, make land use decisions without the benefit of environmental impact statements and public review. They can act quickly and irreversibly. Such actions, taken alone, probably have minimal impact on the peat resource. As a whole, however, landowners can appreciably affect the integrity of Minnesota's wetlands. Theoretically, that very same union of landowners can be used to benefit peatlands. An informed coalition of landowners could sway public opinion in favor of bog conservation.

Central to the question of bog conservation is the problem of informing a large number of people about a complex subject. This paper attempts to explain the ecological processes of peatlands while recording empirical observations in a representative Minnesota bog. The literature review interprets the current knowledge and the field data apply that information in an actual bog. Following the discussion of bog ecology, preservation strategies are presented that offer landowners a guide to the different options regarding conservation and sound, land-use management.

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25 June 1990

What makes this bog? What pushes it gently into this complex mosaic of trees and mosses and shrubs? Intuitively, I know that the soil and water weave a net that supports stalwart spruces and shy sedge wrens. But so much escapes me. Do fragile orchids ensconce themselves in beds of Sphagnum somewhere out there? Will I stumble across a wayward moose? How long has this bog sat here? My ecological consciousness is spawning on the edge of this bog, yet its obscurity perplexes me. What makes this bog?

* * * * * *

Ten thousand years ago, glaciers retreated from what now is northern Minnesota, leaving in their path countless kettle-hole lakes and depressions. These lowlands, along with Minnesota's cool, wet climate, created favorable conditions for bog formation (Malterer 1980, Winkler 1988). The actual age of bogs continues to be investigated, but that bogs are ancient relics of an earlier time is without controversy (Masing 1984, Rybnicek 1984, Winkler 1988).

Pollen studies and development models can allude to the origins and ages of bogs (Winkler 1988, Foster and Wright 1990). Such information is interesting and important, but more recent, man-induced changes have probably impacted bogs more than thousands of years of bog development. Few bogs have escaped human influence, and the representative peatland studied in this paper, Dickerman Bog, also carries the scars of past alterations.

Dickerman Bog is located in St. Louis County, about 20 miles northwest of Duluth, Minnesota. The bog appears to have been, at one time, the westernmost bay of Grand Lake (Figure 1). The interaction between them was disrupted over sixty years ago when a corduroy road was run down the section line, isolating the western portion of the bog from the lake. Sometime later, a driveway to the now-abandoned Erickson cabin was built on the southern edge of the bog. These two roads acted as dams, retarding water drainage and locking the bog into a "bowl." Water drains into the bog from uplands to the west and north, Dickerman Road truncates the bog to the east, and the abandoned driveway inhibits drainage to the south. A culvert

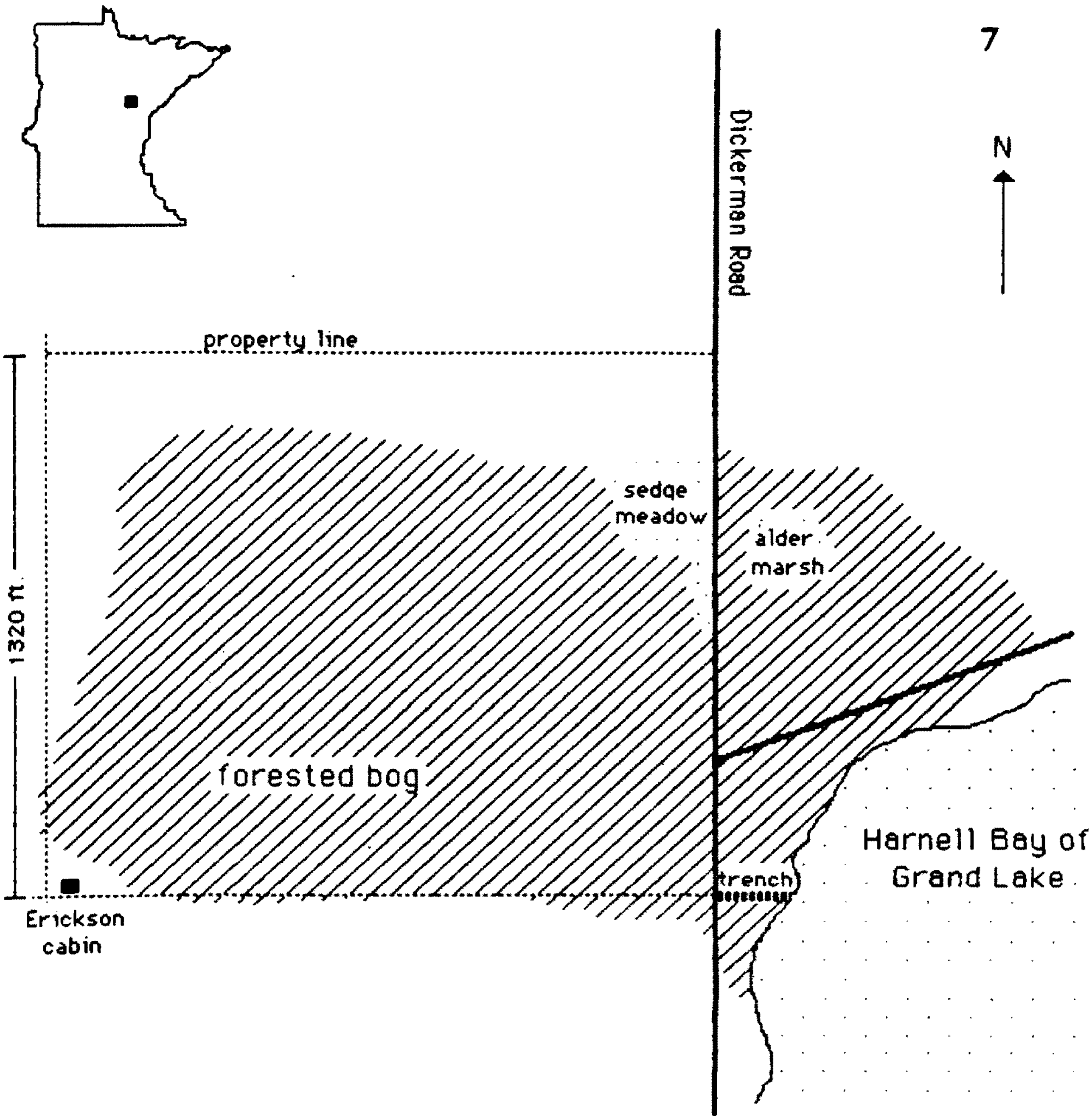

Figure 1. Dickerman Bog. St. Louis County, Minnesota.

at the southeast corner runs under the road and empties into a wide trench that feeds directly into Grand Lake.

By far the most obvious feature in the bog is black spruce (*Picea mariana*) that dominates all but a sedge meadow to the west and an alder marsh to the east. Green alders (*Alnus crispa*) also line the periphery, and *Sphagnum* mosses grow abundantly. The entire bog covers 55-60 acres, but for the purpose of this paper, "Dickerman Bog" will refer only to that part of the bog west of Dickerman Road.

The open sedge meadow appears to be a cultural phenomenon. Residents of the area recall the meadow being harvested for hay in the 1940's, but the *Scirpus* species that characterize its center appear too coarse for livestock fodder. Curtis (1959) commented that prior to modern refrigeration, natural ice was harvested from lakes and rivers during the winter months; mowing the *Scirpus*-dominated sedge meadows produced marsh hay that was used as insulating and packing material in the ice houses. If Dickerman Bog was used as a source for such hay, annual mowing could have retarded further succession, creating a meadow that is held in check by the altered hydrologic regime.

In addition, cattle apparently grazed in the bog. A fence line ran perpendicular to the abandoned driveway about thirty yards west of the sedge meadow. Cattle will eat *Sphagnum*, although the moss is so poor in nutrients it yields very lean beef. The wisdom of grazing cattle in peatlands needs to be questioned. Bog laurel (*Kalmia polifolia*), a toxic shrub, grows abundantly in Dickerman Bog. Since livestock tend to experiment with other forage when their primary source is scarce or unpalatable, poisoning would appear to be a real danger.

Grazing cattle in a bog seems to be a lesson in eccentricity. Bogs remain waterlogged year round, and cattle are not well-suited to the soft surface. A drainage ditch running parallel to the fence line probably lowered the water level far enough to allow grazing for at least part of the year. The ditch may have been dug during the Depression era by a WPA work crew when ditching bogs was a common practice (Arthur Larsen, pers. comm., Glaser 1987). Presently, the ditch appears to be non-functional. It has no visible drainage outlet.

The last period of disturbance occurred twenty years ago when the home owner logged a trail out of the center of the bog to facilitate removal of firewood. Because the removal was done by snowmobile in the winter, there was no need to ditch or raise the trail so it retains much of the bog characteristics.

Presently, the bog is unused. Infrequent disturbances by snowmobiles, off-road vehicles, and ATV's occur in the sedge meadow. The forested bog itself has been almost completely free of human disruption for over fifteen years, although its current condition undoubtedly reflects the uses of the past.

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18 July 1990

Like nothing uphill, this bog. What is underneath it? I hear and read stories of pulling preserved bodies out of bogs in Denmark, probing for undecayed mammoths in former peatlands in Indiana, finding pollen that is thousands of years old unlocking the successional history of bogs in Sweden. What is in this bog? This is a book, a living tome of history, if only one knows how to read it.

There is nothing temporal here. The footpaths I make today compact the peat beneath, and ever so slightly, change the way water moves below. The shrubs that stubbornly flourish here migrated on the heels of an advancing glacier ten thousand years ago. Uncelebrated shrews and voles simply survive, day in and day out.

When I see it change, it moves rapidly. Laurel blooms and fades. Ferns uncurl out of moss beds overnight. Sparrows dart among the spruce. Sunrise burns off the foggy shroud of morning as I watch. Nightly, spiders weave fragile gates of silk between the trees.

And I, of course, moving too rapidly and yet too slow, never open the gates but push through with urgent persistence.

* * * * * *

**"The bogholes might be Atlantic seepage.
The wet centre is bottomless."**
Seamus Heaney

Driving a soil sampler into a blanket of peat does indeed give the impression that bogs may be fathomless. The black muck extends downward through centuries of accumulation, looking very much the same regardless of depth. Perhaps no other single feature defines bog characteristics as does the soil. The processes that occur below the surface affect every aspect of bog ecology. Brady (1974), the Soil Science Society of America (1974), Donahue et al. (1977) and Foth and Schafer (1980) offer in-depth discussions on the nature and properties of peat soils.

Peat consists almost entirely of partially decomposed, compressed plant residues. What appears to be a rich, productive soil, in fact produces precious few nutrients and an unfavorable medium for growth. Plants require nutrients in the form of ionized minerals, but in peat soils, nutrients may be tied up in organic forms, or the organic material may adhere the elements that are not essential for growth.

Nutrients are carried on finely divided particles of soil called colloids. In peat soils, each of these units has a large surface area to carry nutrients. Colloids are negatively charged, and as such, attract nutrients in the form of positively charged ions. This propensity to attract cations is called the cation exchange capacity. Normally, this high capacity to exchange cations results in fertile soil with an abundance of available nutrients for plant growth, but in peat soils, several factors hinder normal processes.

As plants die and fall to the soil surface, microorganisms quickly begin breaking down the plant residues into smaller components. As a result of this microbial activity, a small amount of the organic matter is consumed by the microorganisms, most of it remains as a modified residue called humus, and some is released as carbon dioxide (CO_2), water (H_20), or other elements. Carbon dioxide dissolves in water to yield a weak acid. When in solution, acids dissociate into ions, resulting in large amounts of hydrogen cations freely moving about in the saturated peat material. These hydrogen ions adhere to the colloids. This adsorption not only maintains the acidity of the peat material, it replaces the nutrients that could have otherwise bonded there. Reader (1978a, 1978b) found potassium, nitrogen, and phosphorus deficiencies to severely limit plant growth in bogs. Potassium, as a cation, is pushed off the exchange by hydrogen, and nitrogen is a limiting nutrient in a wide variety of soils. Gorham (1957) suggested that phosphorus, which is deficient in rainwater, most severely limits plant growth in ombrotrophic bogs. As a consequence, the addition of mineral fertilizers to peat temporarily boosts the soil productivity and allows for the cultivation of non-bog species (Sloey et al. 1978, Olenin 1980). Bog plants contribute to their unfavorable environment, and, in a sense, to their continued niche success, by supplying additional organic material for microbial decomposition. Other adaptations of the fascinating bog plants will be discussed in a later section.

As noted earlier, hydrogen ions create an acid environment which translates into a lowered pH. Acidity varies, but in black spruce stands, pH can range from a very acid 3.0 to a near neutral 6.4 (Mitsch and Gosselink

1986, Jeglum 1971). A litmus test of Dickerman Bog's peat indicates that pH approaches 3.8 in the forested bog and 4.0 in the sedge meadow. Although these figures are only rough estimates, they concur with Jeglum's (1971) vegetational index for pH. He found that black spruce, which is the dominant tree species in Dickerman Bog, corresponded most closely to a pH of 4.0-4.9, and the understory shrubs were found in a slightly more acid environment. In effect, the vegetation of bogs acts as a map to decipher the chemistry of the soil.

The acid environment of a bog not only complicates nutrient availability, it also hinders microbial action, thereby leaving organic residues undecomposed. Bacteria and fungi work optimally in near neutral pH, and at temperatures of 95°F (Donahue et al. 1977). These conditions are not often found in ombrotrophic bogs. The overwhelming obstacle to decomposition, however, is the anaerobic environment that persists in a saturated soil (Mitsch and Gosselink 1986).

In upland soils, air diffuses readily into the spaces between colloids. In wetlands, water surrounds the soil particles and displaces the oxygen that normally is available to plant roots and microbes. Additionally, gases diffuse much slower through liquid than through air, so crucial oxygen is not only displaced, it is impeded by the ever present water. In fact, only a shallow, top layer of soil is oxidized. Although this is important to certain chemical transformations, the oxygen found in the upper layer of soil is not very accessible to microorganisms deeper in the soil.

Fungi are decomposing powerhouses. When oxygen becomes limiting, however, fungi give way to slower-acting anaerobic bacteria (Larsen 1982).

Plants continue to drop needles, leaves, and other residues regardless of bacterial efficiency, and as a result, bogs accumulate organic matter faster than it can be broken down. Furthermore, bog plants contain hard-to-decompose lignins and cellulose, which likewise add to the layer of organic residue on the surface. This partially decomposed matter acts as a rooting medium for new growth. As the new growth dies, partially decomposes, and in turn encourages additional growth, the cycle eventually creates a layer of organic material that never completely decays. This peat layer then is a continually growing, renewable--albeit slowly--soil.

Peat accumulates at different rates depending on climate, hydrology, and vegetation. Accretion rates in northern Minnesota varied from two inches per century for moss peat (Heinselman 1963), to almost 50 inches per century on some sedge mats (Leisman 1953). In a similar climate, moss peat in Britain accumulated at a rate of one to 3.5 inches per century (Moore and Bellamy 1974), while some saw grass peat in southern Florida amasses on the order of six inches per year (Davis 1946, in Moore and Bellamy 1974).

Peat does not generally pile up with abandon, however. As more material accumulates, it condenses the peat below it, and eventually the compressed matrix is held in check by the hydrologic regime. Nonetheless, peat accumulates to impressive depths. Curtis (1959) cites evidence of a bog containing 40-50 feet of peat, but the depth of the United State's peatlands more commonly average seven feet (Maly and Sabri 1980). Several probes with a sampler indicate that the soil of Dickerman Bog exceeds eight feet in depth. Assuming that Dickerman Bog closely parallels Heinselman's (1963) study site and that rates of accumulation remain constant, the lowermost layers of peat in the bog may surpass 4800 years of age. Incredibly, even the oldest peat contains partially decomposed plant residues that are obvious with the unaided eye.

Because the conditions of a bog slow microbial action but do not arrest it, peat can be defined by its degree of decomposition (Farnham and Finney 1965, Malterer 1980, Schwerdtfeger 1980). Fibrist peats, those that are the least decomposed, contain over 67 percent recognizable fibers. Hemists contain 33-67 percent fibers, and saprist peats are the most decomposed, with fibers comprising less than 33 percent of the soil. Ingram (1978) distinguishes two layers of peat: the acrotelm, or upper layer, and the lower layer, or catotelm. The acrotelm corresponds to the fibrist peat of the surface where plant residues are relatively young (Boelter 1974, Johnson 1985). Dickerman Bog contains mostly hemist peat, although it tends towards saprist near the bottom. The acrotelm, which extends ten inches down from the surface, consists almost entirely of moss and root material.

Dead and decaying plant materials create peat soils, but the direction of bog succession often acquiesces to a living moss genus called *Sphagnum*. A discussion of bog soils necessarily includes *Sphagnum* because of the plant's amazing ability to change the chemistry of the peat, as well as alter the topography of the bog.

Sphagnum is found in abundance in northern bogs, but will grow on drier sites where the humidity remains high enough to support it (Gorham 1957). *Sphagnum* frequently grows in hummocks, or pillowy formations, that give the bog surface an uneven, rolling appearance. The long, fibrous plant bodies grow from the top, and often the lower portions of *Sphagnum* will be dead and decomposing while the top continues to grow (Bland 1971). It prefers sunny, open areas, but when in forested bogs, it gives way to more light intolerant species under dense canopies (Larsen 1982). *Sphagnum* avoids the problems of desiccation and heating in direct sunlight by producing tannins which give the plant a red color that more effectively blocks the sun's rays (Bland 1971). The reds, greens, and intermediate hues create a characteristic, muted mosaic in *Sphagnum* bogs.

Sphagnum has little competition in bogs. It easily overtops other mosses in all but the shadiest conditions (Masing 1984). During infrequent droughts, hummocks can retain moisture even when the surrounding hollows are dry due to *Sphagnum's* amazing ability to hold 10-25 times its dry weight in water (Andrus 1986).

Regardless of how well-adapted it is to living in bogs, *Sphagnum* widens the gap between itself and its competitors even further by acidifying its microenvironment. The moss releases hydrogen ions through its root system in exchange for cations such as calcium and magnesium (Moore and Bellamy 1974, Larsen 1982, Andrus 1986). This buffers the moss against basic inputs, and also makes the soil more unsuitable for invader species.

Sphagnum's influence in bogs extends beyond the plant's immediate environment. With time, the moss can alter the topography and encourage outward expansion (Gorham 1957). As a lowland bog builds peat from *Sphagnum* residues, the surface eventually isolates itself from the influence of groundwater. *Sphagnum's* high capillary action enables it to pull water upward, thereby allowing continued peat accumulation. Eventually, however, the pull of gravity overcomes the capillary action, and on the drier, aerated surface, decomposition resumes at an increased rate. At this point, as long as the water table remains constant, the bog reaches its optimum height.

While the center of the bog accumulates peat, the margins receive aerated surface flows and the plant residues decompose more rapidly. Consequently, the bog forms a convex cross section. This raised, or ombrotrophic, bog receives all nutrient inputs through precipitation. The center cap may be as much as 15 feet higher than the margins (Hobbs 1980), but generally is only detectable with a topographic survey.

Any horizontal expansion is controlled by hydrology (Malterer 1980). When drainage along the margin is impeded, peat forms around the periphery, causing the bog to expand and further hinder drainage. This in turn encourages additional peat accumulation, and over a period of time, the bog may creep out of its basin and move uphill. The process of horizontal expansion, or paludification, creates blanket bogs, peatlands that lay over the surface of the land like a blanket.

Dickerman Bog appears to be ombrotrophic. Upon examination of aerial photos, Malterer (pers. comm.) was able to detect what may be a raised cap. More conclusively, the vegetation suggests that the bog is nourished solely by rain water. The vegetational indexes that point to this relationship are explained later during the discussion on hydrology.

Raised bogs are common peatland types in Minnesota, and as such, gain small praise. The unusual landforms that indicate richer peatlands with greater diversity garner more attention among conservationists. For better or worse, though, raised bogs are not entirely forgotten: They receive considerable scrutiny from developers, peat harvesters, and others.

Out of the peat bog and into the fire

Historically, peat fueled fires, supported crops and timber, improved soils, and nourished livestock (Kivinen 1980, Larsen 1982). Similar uses, along with newer, more inventive ones, continue today. Farnham (1974) commented on the success of using peat as a wastewater filter in Minnesota campgrounds, and Bland (1971) noted that medics used *Sphagnum* moss as a wound dressing and bandage in World War I. As ingenious as these applications are, by far the most common uses of peat world wide are for fuel and agriculture.

Although the United States has only recently dabbled in peat as an energy source, European countries traditionally used peat as a furnace fuel where regionally feasible. Peat produces more energy than wood per unit, and approaches that of low-ranked coal (MN DNR 1987). Prior to 1980, Leningrad met 20 percent of its fuel needs with peat, and Ireland covered around 25 percent of its energy demand with peat products (Bramryd 1980). Peat can be prepared for fuel use in several ways. Sods and bricks are dried, compressed peat that are burned in a specially fitted furnace. Gasification of peat involves converting solid peat into natural gas. The State of Minnesota experimented for a time on the economic feasibility of peat gasification and peat sods to meet energy demands, but met with mixed results (MN DNR

1987). Peat probably will not be a major energy source in the United States until the current energy scenario changes.

In European countries, vast quantities of peatlands support a thriving agriculture. In Germany, over 80 percent of the peatland has been cleared for agriculture, and in Poland, over 70 percent (Kivinen 1980). Pyachenko (1980) commented that the drainage of peatlands in the USSR is common and "a progressive measure aimed to improve the water regime and to increase fertility of these poorly drained soils." On the other hand, some concern exists whether peat extraction in Canada may jeopardize water resources (Moore and Bellamy 1974). In Minnesota prior to 1980, 650,000 acres of peatlands were lost to agriculture, with an annual reclamation rate of 2400 acres (Kivinen 1980).

Horticultural products consume most of the harvested peat in the United States. *Sphagnum* moss peat added to soils increases water holding capacity and decreases compaction. Lower quality reed-sedge peat can be packaged either alone or with additives, and be sold as potting soil or fertilizer (Ted Tower pers. comm.).

Although the United States contains an estimated 53 million acres of peatlands (Maly and Sabri 1980), the demand for horticultural products has always been met with a large percentage of Canadian *Sphagnum* peat. Minnesota, with nine horticultural operations, is not recognized for having high-quality peat (MN DNR 1987). In the 1980's, the DNR attempted to improve Minnesota's image as a horticultural producer, but Canadian imports still capture large shares of the U.S. market (Ted Tower pers. comm.).

Peat mining, whether for fuel or for horticultural purposes, raises several questions. The small horticultural operations in Minnesota barely impact the total peatland area in the state, but they nonetheless extract what for all practical purposes is a non-renewable resource. In economic terms, peat is as renewable as petroleum. Fuel peat extraction operates on a much larger scale. A peat gasification plant proposed for northern Minnesota in 1975 would have mined 491 square miles of peat for an expected 20 years of fuel (Boffey 1975).

As organic accumulators, peatlands act as carbon sinks. When organic matter oxidizes by burning or simple decay, it releases CO_2 into the atmosphere. Carbon dioxide is one of the so-called "greenhouse gases" that have received so much attention as a possible precursor to global warming. Bramryd (1980) warned that the oxidation of several thousand years of organic accumulation could affect the global carbon dioxide balance.

Research continues into different uses for peat. The current energy situation tempts us to look upon peat as an exciting alternative energy source, and for Minnesota, where energy imports always exceed exports, that possibility is especially attractive. But peat needs to be considered as simply another carbon based fuel. If global warming is indeed a reality, peat energy will only exacerbate that problem. And unlike petroleum and coal, peat directly supports a unique habitat type and all the benefits that accrue with it.

* * * * * *

29 June 1990

This is no summer vacation. How can it be that there are only a million or so species of insects in the world, and they are all buzzing around my head right now? I think I will subtitle my paper "Ten techniques for effective mosquito defense." And those moronic red-winged blackbirds that dive bomb me when I walk past their alder. And the black holes that instantaneously suck in most of my lower body only when I am carrying three hundred dollars of camera equipment. Why couldn't I be studying ecology of some friendly, charitable, terrestrial forest?

I must have done something wrong in the past to be cursed with this liking for bogs.

* * * * * *

"As long as the water is troubled it cannot become stagnant."
James Baldwin

Van Nostrand's Scientific Encyclopedia (1983) defines hydrology as the study of water in relation to its occurrence in lakes, streams, and underground structures. Hydrology is all that, and much more. Hydrology determines the way nutrients get into a system, how they move once they are there, pathways for water to leave the system, and countless other intricacies.

Wetlands are an anomaly in the hydrologic science, not quite aquatic, and not quite terrestrial. Perhaps that is never more obvious than in a bog, where the surface appears to be relatively dry, but each footfall sinks into pillows of *Sphagnum* and comes up dripping. Hydrology defines wetlands, but what does it define them as?

Wetland interpretations are as diverse as wetlands themselves. A single definition of wetlands needs to encompass not only peat bogs, but also shallow lake bays, temporal potholes, and the Everglades. In each of those wetlands types, the soils, plant species, and wildlife vary, leaving the hydrologic regime as the only common feature to define the differences and similarities that set wetlands apart from all other terrestrial and aquatic ecosystems. Currently, the most widely accepted definition of wetlands is found in Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979):

> Wetlands are transitional between terrestrial and aquatic systems...[and] have one or more of the following three

> attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Wetlands have to do with water. Not surprisingly, peat bogs also obey the laws of hydrology, although at first glance, water seems to do little but stagnate. In fact, though, moisture, along with pH, critically affects community vegetation in bogs (Jeglum 1971).

Gosselink and Turner (1978) define the four attributes of wetland hydrology that most affect the ecosystem. The source of the water determines the nutrient and toxin content, while the velocity defines the turbulence and particle load. Renewal rate indicates how rapidly the water in the wetland is replaced, and the timing determines how frequently the wetland is inundated with water. Not only are these features difficult to measure, they vary in importance between bogs.

Usually, water enters a bog by way of the surrounding mineral soils, groundwater inflow, or precipitation (Heinselman 1963). As discussed earlier, raised bogs are notoriously mineral-deficient because most of their nutrients come from rainfall, giving rise to the term ombrotrophic. Some groundwater may percolate upward through the peat soil, but generally peat acts as a barrier to percolation (Heinselman 1970, Gosselink and Turner 1978), although the resistance to water movement decreases as the peat's fiber content increases (Verry and Boelter 1978). Fens, and their characteristically diverse vegetation, develop where shallow soils allow for influx of mineralized groundwater. This phenomenon is apparent in Conway's

(1949) "marginal fen," where shallow peats and groundwater input along the periphery, in addition to surface run-off, permit the growth of minerotrophic vegetation.

The interaction between peat and groundwater cannot be determined without extensive tests, although the water table in nonraised peatlands is generally thought to be at or near the surface (Boelter 1974, Reader 1978b, Mitsch and Gosselink 1986). Fortunately, peatlands give rise to distinctive vegetation that indicates the water source (Heinselman 1970, Larsen 1982, Masing 1984, Winkler 1988). As a result, vegetation distributions between bogs and fens are usually mutually exclusive. Jeglum (1971) expands on the relationship between plant species and moisture through a vegetational index that estimates the average depth to water in bogs. Although this depth to water does not necessarily indicate the depth to groundwater, in some instances the two measurements are one in the same.

Dickerman Bog's vegetation suggests an ombrotrophic bog with a marginal fen along the upland slopes. Heinselman (1970) identified six species that were indicative of ombrotrophic waters, five of which are found in Dickerman Bog. The alders and willows along the periphery correspond to Conway's (1949) description of a marginal fen. Jeglum (1971) estimated that black spruce stands indicated a moist surface with water 24-31 inches below the surface, and heath shrubs would predict a similar or slightly higher water level. Several shallow pits dug in Dickerman Bog quickly filled to within eight inches of the surface, showing that the water level exceeds Jeglum's estimates. Quite possibly, the damming action of the two roads accounts for this discrepancy. Because the water level appears to have been altered, the succession of the forested bog may have been arrested. The information presented in this paper may, in time, form the baseline data for future assessments of Dickerman Bog's development.

Water velocity usually defines many wetland features, but in a bog velocity measurements reinforce the conception that water in bogs doesn't flow, it oozes. What causes water, which usually moves rapidly, to creep through a bog?

Hydraulic conductivity measures how far water will move through a substrate in a given period of time. In peats, hydraulic conductivity decreases with an increase in decomposition, meaning that fibrist peats pose less resistance to water movement than saprists (Boelter 1974, Verry and Boelter 1978). Peat holds 90-92 percent water by weight (Pyachenko 1980), meaning that the soil binds up much of the water. Only the acrotelm, or active layer, of peat soil allows free movement of water. Johnson (1985) noted that less than one percent of the water that leaves a bog does so from the decomposed layers below the acrotelm. This decrease in hydraulic conductivity translates into a magnified renewal time, making these two attributes of hydrology closely related.

Most water leaves a bog through the slow process of vaporization (Verry and Boelter 1978), thereby adding to the already protracted renewal time. Transpiration is the release of water vapor from plants, and along with evaporation, constitutes a single unit called evapotranspiration. In hot, dry climates, evapotranspiration leads to desert conditions. In the north, however, it is oftentimes less than precipitation. As a result, bogs remain wet year round even when their sole source of water is precipitation.

Water sits on the surface of Dickerman Bog only during the spring, and then only in the sedge meadow. For the rest of the year, the water level drops below the surface, meaning that most of its water must move through the peat soil, slowing down the velocity and renewal rate. There is no channelized flow through the bog, and the culvert at the southeast corner appears to simply collect seepage from the *Sphagnum* and peat. The outflow through this point is negligible compared to the size of the bog.

Heinselman (1970) noted that plant species richness increased with water velocity. Here again, hydrology dictates the vegetation. Dickerman Bog's conifer forest contains ten vascular plant species and two bryophytes (Table 1). Compared to the flowing, swamp forests of Heinselman's study, which contained a total of 49 vascular and nonvascular plants, the bog is a species wasteland. Although the last figure is a compilation of several different swamp forest sites, it nonetheless gives an indication of the difference in species richness.

The last attribute of hydrology, timing of inundation, is somewhat meaningless in northern bogs. In tidal and temporal wetlands, the length of inundation may vary from several hours a day to six months a year, but peat soils are nearly always saturated. Only during prolonged dry cycles does the peat soil release water. Although the surface dried out considerably during late summer, Dickerman Bog remained too wet for anything but rubber boots from June through September despite a dry, hot August. Surface plants such as *Sphagnum* never showed any indications of water stress, and tire ruts in the sedge meadow retained water nearly all summer.

Like the microorganisms discussed earlier, plants that grow where swamping is continual must deal with an oxygen shortage year round. *Sphagnum* adapts to anoxia by diffusing oxygen through its aerial leaves and down to the roots (Johnson 1985, Mitsch and Gosselink 1986). Still other plants respire anaerobically when anoxia sets in. In any case, their adaptations to the oxygen-poor, nutrient-deficient, harsh environment of bogs is a remarkable lesson in habitat selection and evolution.

"Water, water everywhere,
Nor any drop to drink."

Samuel Taylor Coleridge
"Rime of the Ancient Mariner"

At first glance, bog plants seem to be living in a vegetation utopia. As noted, however, the black soil contains few nutrients, and the continual water saturation stresses even the hardiest plants. During dry years, at least, when water is at a premium for upland species, bog species appear to be occupying a favorable niche.

Ironically, though, desiccation endangers plants every year (Larsen 1982). In early spring, when plants begin photosynthesizing, they start to transpire water through the open stomata in their leaves. In the low-lying, waterlogged soil of bogs, where temperatures lag behind upland environments, plants often begin transpiring water when their roots are still encased in ice. Frozen roots do not readily take up water, and bog plants in essence are pumping water out of their leaves and replacing only a fraction through their roots. During the waning weeks of winter, the bog environment literally becomes a watery desert, although desiccation remains a threat year round. Winter-driven snow and wind acts as a dry abrasive on exposed leaves, pulling precious water from dormant plants. During the benevolent summer months, low oxygen content, toxins, and acidity combine to interfere with water absorption.

Plants of the forested bog (Table 1) adapt to the threat of desiccation in a variety of ways. They also meet the challenge of a short growing season, nutrient deficiencies, and competition with innovation. In short, the raised

Table 1. Plant species of the conifer forest of Dickerman Bog.

Tamarack	*Larix laricina*
Black spruce	*Picea mariana*
Cotton grass	*Eriophorum spissum*
Sphagnum	*Sphagnum* spp.
Common hairy cap moss	*Polytrichum commune*
Oak moss	*Evernia mesomorpha*
Three-leaved false Soloman's-seal	*Smilicina trifolia*
Marsh fern*	*Thelypteris palustris*
Green alder*	*Alnus crispa*
Quaking aspen*	*Populus tremuloides*
St. John's-wort*	*Hypericum virginicum*
Self-heal*	*Prunella vulgaris*
Small cranberry	*Vaccinium oxycoccos*
Velvet-leaf blueberry	*Vaccinium myrtilloides*
Laborador tea	*Ledum groenlandicum*
Bog laurel	*Kalmia polifolia*
Bog rosemary	*Andromeda glaucophylla*
Leather-leaf	*Chamaedaphne calyculata*

*indicates species found only along margins bog and its vegetation are lessons in nutrient hoarding and water economy.

On being tall in a bog

Black spruce dominates most ombrotrophic bogs. Tamarack (*Larix laricina*) commonly grows on the sunny margins, being extremely shade intolerant. It often proceeds black spruce in the successional sequence (Curtis 1959, Larsen 1982). A close inspection of the spruce reveals a thick, resilient coat on each of the needles. This cuticle acts as a barrier to unnecessary transpiration during times of water stress. Such a protective coating is crucial to plant species that do not drop their needles during the cold, windy dormant season.

Being evergreen, like black spruce, constitutes an obvious advantage where the growing seasons are short. A tree that retains its needles for more than one growing season starts photosynthesis earlier in the spring than a species that replaces its leaves every year. Additionally, from the tree's point of view, being evergreen means that precious energy is not funnelled into complete leaf replacement every year.

A tree that retains its needles, however, presents more of an obstacle to wind. The poor substrate in bogs does not allow for solid rooting, and evergreens run the risk of toppling over in heavy gusts. Even if the substrate improves deeper in the peat, trees must send out shallow root systems in order to take advantage of the meager oxygen that penetrates below the peat surface. Black spruce, like tamarack, has a wide, shallow network of roots that extend out in all directions around the tree (Curtis 1959).

As *Sphagnum* continues to accumulate, trees are in danger of being overtopped by peat. Black spruce and tamarack grow a new set of roots a tier above the old roots when peat accumulation progresses too far. This unusual phenomenon poses interesting problems for determining the age of trees. The original stump of a tree may be buried beneath a yard or more of peat with only the younger top showing. Heinselman (1963) documented two cases where the tree at present ground line had fewer annual rings than did the tree stem at the site of the original main root. In one case, the tree was only barely keeping ahead of the aggressive *Sphagnum* growth.

Competing with an ever-growing *Sphagnum* carpet jeopardizes first-year seedlings. Curtis (1959) points out that young seedlings are often smothered by *Sphagnum*. Black spruce and tamarack compensate for this by sprouting shoots off their shallow root systems. This gives new growth a head start on *Sphagnum* accumulation and accounts for the concentric circles of young trees often surrounding a parent conifer.

Despite all these ingenious adaptations, black spruce is not a particularly successful-looking tree. It often appears asymmetrical, stunted, and spindly. Tamarack is more pleasing with its soft, deciduous needles and healthier appearance. In Dickerman Bog's conifer forest, black spruce appears to shade out tamarack everywhere but the margins along the sedge meadow. The tamaracks become increasingly younger as one progresses from the black spruce into the sedge meadow, suggesting that tamarack is slowly invading the open area.

To evergreen or not to evergreen

The heath shrubs (Ericacae) often cover a large portion of a bog's surface, and without a doubt, these arctic species are among the most fascinating. Like black spruce and tamarack, the ericads appear to be playing a game of adaptive Russian roulette. Evergreenness versus desiccation, water economy versus a more competitive habitat: any one of these could be the lethal choice. Fortunately for the ericads, a long evolutionary history already evened the odds.

Many of the ericads' adaptations to desiccation are geared toward modified leaves that minimize the effects of drying winds. Whether this entails reducing the speed of wind that flows over open stomata, or protecting the entire leaf surface, the ericads exhibit a wide variety of structures to meet the need.

The undersides of Laborador tea (*Ledum groenlandicum*) leaves are packed with dense, brown hairs. This thick tomentum reduces water loss by acting as a barrier to wind. Bog laurel and bog rosemary (*Andromeda glaucophylla*) lack the tomentum of Laborador tea, but they exhibit rolled under, or revolute, leaves with a white, waxy coating beneath. Tiny, rust-colored scales on leather-leaf (*Chamaedaphne calyculata*) act much the same way. Other adaptations seen in the ericads include a thick waxy coating on the entire leaf surface, and low, wind-protected plant bodies.

Several of the ericads are semi-evergreen. Leather-leaf, bog laurel, and Laborador tea retain their leaves well into their second growing season. The older leaves that have overwintered apparently contribute to the growth of incoming leaves (Reader 1978a). Shortly before abscission, leaves that are about to fall translocate the minerals they contain back into the plant body, thereby conserving the nitrogen, phosphorus, and potassium that is so limiting in bogs.

Ironically, the adaptations that make the ericads so successful in bogs evolved in an entirely different climate. Further north, they are upland species of the cold, dry arctic (Larsen 1982). The Great Lakes region appears to be the southern edge of many of the ericad's ranges. Why would species adapted to a dry, upland environment be successful in wet, lowland habitat? Larsen (1982) points out that the ericads may survive in southern bogs simply because they have no competition from other species. He further stresses this point by stating "we must keep in mind the possibility that [the ericads] survive where they do despite, and not because of, their distinctive morphological characteristics." For whatever reason the ericads survive in the Great Lakes region, they are a unique addition to the landscape and are intricately tied to the welfare of bogs.

Dickerman Bog contains six species of heath shrubs Table 1. The shrubs are quite evenly distributed across the expanse of the forested bog, except for the periphery where black spruce grows more abundantly. Malterer (pers. comm.) suggested that the vigorous band of black spruce is due to an input of nutrients near the margins. In the shade of the dense spruce overstory, all the ericads except for Laborador tea fall away. Laborador tea is a light intolerant species (Larsen 1982), and thrives under the dense spruce stands.

Two additional ericads, small cranberry (*Vaccinium oxycoccos*) and velvet-leaf blueberry (*Vaccinium myrtilloides*), grow sparsely in the bog. Cranberry is found in close association with leather-leaf along the sunny margins, but falls away gradually as the spruce stand shades the surface. Fortunately, with its distinctive trailing stems, cranberry is easily identified, for the plants flower early in the spring and bear little fruit. Blueberries, which were slightly more prolific, ripened by mid-August but were too dispersed to harvest.

Verdant carpets, living garland

In addition to *Sphagnum*, Dickerman Bog supports *Polytrichum commune* , or common hairy cap moss. This is one of the most widely distributed mosses in North America, and is also the largest in the *Polytrichum* genus (Bland 1971). Hairy cap moss grows in close association with *Sphagnum* in sunny areas, and is quite commonly noted in the literature. Janssens and Glaser (1986) note that *Polytrichum strictum*, a close relative of hairy cap moss, most frequently occupies drier hummocks where the *Sphagnum* is not as aggressive. In Dickerman Bog, hairy cap moss grows most abundantly along the margin, but is present throughout the entire conifer forest.

Much of black spruce's ragged appearance comes from the lichens that cover the spruce's branches and trunk. In Dickerman Bog, two foliose lichens were unidentified. A third, arboreal lichen, oak moss (*Evernia mesomorpha*) commonly drapes its entangled, branched hyphae across the limbs of living trees. Its gray-green color is distinctive, and like all members of the genus, contains essential oils that are most fragrant when growing on oaks, hence the name (Bland 1971).

Only two species span both the conifer forest and the open sedge meadow, *Sphagnum* and three-leaved false Soloman's-seal (*Smilicina trifolia*). False Soloman's-seal apparently adapts itself to all conditions except the most shady, being found everywhere in Dickerman Bog except under the dense spruce overstory. As widespread as it is, this small monocot is easily missed among the taller, more noticeable vegetation. Jeglum (1971) found false Soloman's-seal to be an indicator of an acidic soil, and Dickerman Bog meets that requirement across both the forested bog and the sedge meadow.

Sea of sedges

For purposes of convenience, the open sedge meadow refers to that portion of Dickerman Bog not populated by conifers or alders (Table 2). Because the meadow appears to be a cultural phenomenon, there is very little information on similar open meadows in connection with a typical spruce bog. Curtis (1959) discusses the ecology of Wisconsin sedge meadows, and although his discussion includes several of the same species found in Dickerman Bog, there are important differences. First of all, Curtis' meadow does not contain *Sphagnum*, whereas Dickerman Bog's sedge meadow has a sparse, but obvious *Sphagnum* carpet. Secondly, the acidity of the Wisconsin meadows ranged from 4.9 to 6.6, considerably less acidic than Dickerman Bog. And most importantly, Curtis commented that the peat under the sedge meadow indicated that the site was once forested and was

Table 2. Plant species of the sedge meadow of Dickerman Bog.

Canary grass*	*Phalaris arundinacea*
Ticklegrass	*Agrostis scabra*
Canada bluegrass	*Calamagrostis inexpansa*
Spike rush*	*Eleocharis obtusa*
Wool grass	*Scirpus cyperinus*
	Scirpus atrovirens
	Carex bebii
Sphagnum	*Sphagnum* spp.
Three-leaved false Soloman's-seal	*Smilicina trifolia*
White camass*	*Zigadenus elegans*
Water arrum	*Calla palustris*
Wild lily of the valley*	*Maianthemum canadense*
Blue flag*	*Iris versicolor*
Water plantain*	*Alsima subcordatum*
Sensitive fern	*Onoclea sensiblis*
Willow	*Salix* spp.
Goldenrod	*Solidago* spp.
Bedstraw	*Galium tinctorium*
Water hemlock	*Cicuta bulbifera*
Meadow-sweet	*Spiraea alba*

*indicates species found only along the edge moving toward a drier stage populated by willows, alders, and dogwood. The tamarack and black spruce of Dickerman Bog appear to be invading the sedge meadow, not retreating from it.

Despite all this, there is good reason to compare Curtis' meadow with Dickerman Bog. The meadows probably look similar. *Scirpus* species are the dominant sedges in both meadows. Additionally, Curtis noted that acidity of the sedge meadows increased with northern latitudes. A sedge meadow of the type Curtis described may approach a pH of 4.0 in northern Minnesota, and could conceivably support *Sphagnum* mosses. And lastly, if Dickerman Bog's meadow is not a cultural phenomenon at all, but rather a natural meadow, it is entirely possible that the man-induced changes to the hydrologic regime did reverse or halt the meadow's progression to a drier alder or willow thicket. The bog on the east side of Dickerman Road, which was at one time part of Dickerman Bog, also has a non-forested area that currently supports a thick alder thicket.

Scirpus cyperinus, or wool grass, and *Scirpus atrovirens* grow abundantly in the center of the meadow, but fall away quickly where leather-leaf and cranberry are established. Willows (*Salix* spp.), cattails (*Typha* spp.), and canary grass (*Phalaris arundinacaea*) are well established along the margins of the meadow, indicating the presence of some mineral water influence. Because these species occur most abundantly along the northern and western margins of the bog, mineral input most likely arises from surface run-off from the adjacent upland.

Marsh ferns (*Thelypteris palustris*) flourished in the zone between the forested bog and sedge meadow. Although the plants appear to be distressed by the acidic soil, the yellowish-green fronds are characteristic of the species (Niering 1985). Sensitive ferns (*Onoclea sensiblis*), somewhat ironically, are not affected by acidic conditions. The name stems from the susceptibility of the plant to early frost (Fernald 1950). The sensitive ferns are common both in the sedge meadow and along the abandoned driveway at the southern edge of the bog.

What does the next several thousand years hold for Dickerman Bog? Undoubtedly, the appearance of the landscape changed since the last ice age, and succession continues today. Following the glacial retreat, the present-day margins of the bog were probably prime lake shore property. In time, the lake filled in, established a sedge community, gave way to an open bog ecosystem, and progressed to the forested bog apparent today. The future may yield a cedar-fir forest where black spruce and tamarack now flourish, and the sedge meadow may simply be a later stage of that same succession (Larsen 1982, Benyus 1989). It is doubtful, however, that the bog will progress to a terrestrial, upland forest as was thought in the past (Curtis 1959). Peat, along with the action of *Sphagnum* and climate, is a self-perpetuating soil. Rather than holding out for the possibility that the peat bog will become, someday, a more useful, upland landscape, it would be preferable to look upon the bog as a unique part of the northern mosaic, and appreciate the diversity it lends.

The heel of Achilles

Like most Minnesota bogs, Dickerman Bog contains a small number of abundant, common species. For one reason or another, the bog does not contain suitable habitat for those species currently in danger of extinction, an unfortunate fact for species declining due to habitat loss (Table 3). Many rare plants are restricted to peatlands with mineral influence, categorically rejecting most ombrotrophic bogs as unsuitable (Glaser 1987).

Some plants are not necessarily threatened or endangered, but because of their unusual nature, are charismatic additions to the bog environment. Carnivorous plants such as the pitcher plants (*Sarracenia purpurea*), sundews (*Drosera* spp.), and bladderworts (*Utricularia* spp.) probably evolved as a result of a nutrient-poor environment. Insects, isopods, mites, and spiders are a quality source of nitrogen, which is often the limiting factor for bog plants (Larsen 1982, Benyus 1989).

Sundews, tiny rosettes of leaves covered with sticky resinous hairs, sparkle in sunlight. *Sphagnum* mosses easily overtop sundews, making them difficult to find in all but the warmest months (Johnson 1985). Pitcher plants are much taller, and their red and green leaves are quite obvious. Johnson (1985) noted that pitcher plants require animal supplements only during flower and fruit development, since the plant reduces secretion of digestive enzymes after seed production. The bladderworts are restricted to the open water of bog pools (Larsen 1982). Upon stimulus by insects or protozoans, their hollow leaves expand, sucking the unlucky individual inside the actual leaf.

Table 3. Rare, endangered, or threatened plant species of Minnesota peatlands. (MN DNR 1986, Glaser 1987).

	Carex exilis
	Carex sterilis
Sooty beak-rush	*Rhynchospora fusca*
Hair-like beak-rush	*Rhynchospora capillacea*
	Cladium mariscoides
Small beak spike-rush	*Eleocharis rostellata*
Bog rush	*Juncus stygius*
Mountain yellow-eyed grass	*Xyris montana*
English sundew	*Drosera anglica*
Linear-leaved sundew	*Drosera linearis*
Ram's-head lady's slipper	*Cypripedium arietinum*
Four-angled water lily	*Nymphaea tetragona*
Baked apple berry	*Rubus chamaemorus*

The carnivorous plants prefer ombrotrophic peatlands, and outside the bog environment are difficult to find (Larsen 1982). Perhaps one of the bog's saving graces is that it provides habitat for species not often found in the uplands. Many of the ericads, black spruce, and the carnivorous plants all prefer, and may in fact require, the continued health and presence of ombrotrophic bogs. Additionally, the vegetation of bogs supports unusual wildlife. Bogs, truly, are like nothing uphill.

* * * * * *

10 July 1990

Very sobering to bend down nineteen times and set traps, with the drizzle slipping silently down cattails. It's a different world three inches from the ground where shrews and voles prevail. So silent, so elemental, so terrestrial. We humans would like to think we are in touch with our earth, but we are really Gullivers in a Lilliputan world.

* * * * * *

"How dreary--to be--Somebody!
How public--like a Frog--
To tell one's name--the livelong June--
To an admiring Bog!"
Emily Dickenson

Usually, wetlands enjoy a wide variety of both aquatic and terrestrial wildlife. The bog fauna, on the other hand, is an under-represented ecological bystander. In marshes, muskrats influence the vegetation and hydrology by feeding on cattails. Beavers create and destroy wetlands by dam building. Bogs, on the other hand, contain a handful of mammals and birds that seem to simply endure, without fanfare and without leniency.

Where the wild things are

Many of the animals that utilize the bog habitat do so only periodically or along the edge (Table 4). Few species require peatland habitat, and even fewer use peatlands exclusively. Marshall and Miquelle (1978, in MN DNR 1987) compiled a list of only 20 mammals and 27 birds that depend on peatlands. To be sure, the bog is preferred by only a tenacious few.

Black bears (*Ursus americanus*) were sighted several times near Dickerman Bog. Although Benyus (1989) suggests that bear watchers visit bogs during hot weather to catch a glimpse of the shy black bear, bog use by bears is not well documented. The summer of 1990 was another bumper year for bears in northern Minnesota. When numbers become artificially high, bogs may serve more to isolate bears from humans than actually provide primary habitat.

Table 4. Mammals and birds of Dickerman Bog.

MAMMALS

Black bear*†	*Ursus americanus*
Whitetail deer	*Odocoileus virginianus*
Masked shrew	*Sorex cinereus*
Arctic shrew	*Sorex arcticus*
Northern water shrew†	*Sorex palustris*
Boreal redback vole	*Clethrionomys gapperi*
Meadow vole†	*Microtus pennsylvanicus*

BIRDS

Great Blue Heron†	*Ardea herodias*
Cooper's Hawk*†	*Accipiter cooperii*
Northern Harrier*	*Circus cyaneus*
Eastern Screech Owl*†	*Otus asio*
Pileated Woodpecker†	*Dryocopus pileatus*
Northern Flicker*	*Colaptes auratus*
Alder Flycatcher†	*Empidonax alnorum*
Least Flycatcher†	*Empidonax minimus*
Blue Jay*	*Cyanocitta cristata*
American crow	*Corvus brachyrhynchos*
House Wren†	*Troglodytes aedon*
Sedge Wren	*Cistothorus platensis*
Swainson's Thrush*†	*Catharus ustulatus*
Golden-winged Warbler*†	*Vermivora chrysoptera*
Nashville Warbler†	*Vermivora ruficapilla*
Yellow Warbler	*Dendroica petechia*
Yellow-rumped Warbler	*Dendroica coronata*
Palm Warbler†	*Dendroica palmarum*
Black-and-white Warbler	*Mniotilta varia*
American Redstart†	*Setophaga ruticilla*
Northern Waterthrush*	*Seiurus noveboracensis*
Common Yellowthroat†	*Geothlypis thichas*
Song Sparrow	*Melospiza melodia*
Swamp Sparrow	*Melospiza georgiana*
White-throated Sparrow	*Zonotrichia albicollis*
Red-winged Blackbird	*Agelaius phoeniceus*

* indicates species that was sighted or heard only once
† indicates species that were sighted or heard only along margin

Whitetail deer (*Odocoileus virginianus*) used Dickerman Bog almost exclusively as a corridor between the north and south uplands. Numerous deer trails cut across the conifer forest, although several beds in the alder fen suggested the bog habitat offered thick cover not found in the nearby uplands. Deer occasionally use conifer bogs as wintering areas even though black spruce and tamarack are considered poor forage (MN DNR 1987). Despite this, Dickerman Bog may act as winter habitat because it is small enough to provide easy assess to aspen-populated uplands which is considered a major factor in the suitability of bogs as deer yards (MN DNR 1987).

Small mammals sampled with Sherman live traps attested to the validity of previous studies on site selection in bogs. Presence of meadow voles (*Microtus pennsylvanicus*), arctic shrews (*Sorex articus*), and northern water shrews (*Sorex palustris*) closely corresponded to the habitat preferences determined by Norquist and Birney (1980, in MN DNR 1987). All three species were found in the marginal fen, and arctic shrews were also found in the sedge meadow. Boreal redback voles (*Clethrionomys gapperi*) and masked shrews (*Sorex cinereus*) were common and found only in the forested bog although Norquist and Birney noted that these two species used a wides range of habitats.

Somewhat disappointingly, bog lemmings (*Synaptomys cooperi and S. borealis*) and starnosed moles (*Condylura cristata*) were never trapped in Dickerman Bog. Lemmings are quite difficult to sample, being trap shy. They prefer bogs with heavy grass growth (Larsen 1982). The distinctive starnosed mole prefers low wet places, usually near lakes or streams (Burt and Grossenheider 1976). Dickerman Bog probably doesn't supply suitable habitat for these three species.

On wings of warblers

Censusing the mobile, sometimes secretive avifauna always presents a challenge. As a result, a large number of avian species were sighted only once or along the bog's margin. Edge use by birds is well documented (Anderson et al. 1977, Yahner 1987), and presents problems for habitat classification. Additionally, migratory birds that passed through Dickerman Bog were difficult to sample because of their rapid turnover. Fortunately, the conspicuous or common species tended to be very conspicuous or very common, simplifying identification and increasing observation times.

A Northern harrier (*Circus cyaneus*) was sighted only once hunting on wing above the sedge meadow, a surprising revelation considering the proven presence of small mammals. Arctic shrews are known to inhabit the meadow, but Erhlich et al. (1988) notes that harriers prefer voles, and the raptor left after several futile minutes of hunting.

Sedge wrens (*Cistothorus platensis*) attach nests to the stalks of young sedges in the spring (Benyus 1989). These shy birds appeared to reside in the meadow although no nests were discovered. The gregarious song sparrows (*Melospiza melodia*) and swamp sparrows (*Melospiza georgiana*) also used the sedge meadow. Song sparrows utilize a wide variety of habitats, and it was not unusual to see sparrows along the gradient from alder fen to grassy field to birch stand.

Nashville warblers (*Vermivora ruficapilla*) were usually found along the margin of the bog, although Benyus (1989) noted that these warblers were inhabitants of the lowland needleleaf forest. Yellow warblers (*Dendroica petechia*) and Yellow-rumped warblers (*Dendroica coronata*) were prevalent in the bog and margin. Yellow-rumped warblers are the first birds to arrive in the spring and the last to leave in the fall (Benyus 1989). They were present during the entire field season.

Black-and-white warblers (*Mniotilta varia*) are almost forgotten in the bog literature, but were not uncommon in Dickerman Bog. More frequently found in broadleaved and mixed forests, the black-and-white warbler uses conifer forests in the north (Farrand 1985). Careful consideration must be given to this species as it is sensitive to fragmentation of its breeding habitat (Erhlich et al. 1988).

Forested bogs act as magnets to birders in search of the elusive Connecticut warbler (*Oporornis agilis*), great gray owl (*Strix nebulosa*), and spruce grouse (*Dendragapus canadensis*). These species so often evade the serious birder they are near the top of the American Birding Association's "most wanted list" (Eckert 1983). Although not threatened or endangered, the future success of these species and others like them may depend on the continued presence of quality bog habitat.

Unfortunately, none of these uncommon species were censused in Dickerman Bog. A resident pair of great gray owls could lift an otherwise ordinary peatland into one with ecological significance. As it is, vast numbers of small, ombrotrophic bogs host only common, abundant vegetation and wildlife. Because such bogs are, almost literally, a dime a dozen in northern Minnesota, few provisions have been made for their conservation and preservation. Searching for a suitable method to conserve the unpresuming raised bog is at the least, a challenge, and at the most, a frustrating lesson in gathering grapes from thorns.

Conservation: *n*; the official preservation of natural resources; preservation from loss, waste, or harm. (Morris 1976).

With over six million acres of peatland in Minnesota (Malterer 1980), one must legitimately ask if there is a need to preserve bogs. Peat bogs are a common, and sometimes nuisance, feature of the Minnesota landscape. Admittedly, the drainage or excavation of a single, small peat bog would have little effect on the integrity of the surrounding area. However, drainage does not usually stop with one bog.

At any rate, wetland conversion is against the law. Section 404 of the Clean Water Act, Executive Order 11990, and state regulations prohibit the unpermitted alteration of wetlands (Mitsch and Gosselink 1986, Baldwin 1987). Unfortunately, these programs only slow the rate of loss. Enforcing such widespread policies is next to impossible and serves to reenforce the belief that preservation will be successful when landowners realize and appreciate the intrinsic value of their wetlands.

Simply agreeing that wetland, particularly peatland, preservation is beneficial is only the first step. Land that does not produce an income, does not teem with wildlife, or does not offer aesthetic beauty is often considered a money sink. Peatlands resist development, sport little wildlife, and are not particularly beautiful. As such, they present a drain on the taxpayer's income. The landowner who would like to preserve the integrity of his bog must either voluntarily leave it undisturbed or find an organization willing to buy or accept a donation of the land.

To date, efforts at preservation have been focused toward bogs with rare or endangered species, rare landforms, or scientific value. Such preservation is crucial and welcome. The Minnesota Department of Natural Resources is to be commended for their farsightedness in establishing a peat program, funding research, and inventorying the peatlands in the state. Additionally, the DNR proposed a bill to the Minnesota legislature that would provide protection to eighteen peatlands. Recommendations for Protection of Ecologically Significant Peatlands in Minnesota (MN DNR 1984) discusses the processes leading up to the legislation. The proposal encompasses nearly a half million acres of peatland and watershed protection areas.

The legislation included only those peatlands which exceeded 3,000 acres and represented the best examples of habitat, unusual landforms, or potential research sites. Unfortunately, few peatlands meet more than one or two of the above criteria. Additionally, the legislation was limited exclusively to state land. Although only two percent of the proposed protection areas were privately owned, they were nonetheless left out of the bill. Supposedly, private landowners would have had the option of donating or selling land that was included in the proposed areas.

Despite the DNR's preparation and effort, the legislation was never acted upon, and with the termination of the peat program at the state level, further action on the bill is doubtful. If the bill had passed into law, it would not have provided a vehicle for conservation of privately-owned bogs, but it may have served as a precedent for further conservation measures. As the situation now stands, preservation of private peatlands is without direction.

As impoverished as they are, peat bogs are important facets of the landscape and require some provisions for conservation. Fortunately, that realization is apparent in the private conservation groups throughout Minnesota, as well as some programs at county, state and federal levels. The methods to actually conserve ecosystems can be as creative and varied as the landscape itself.

Fee-simple acquisitions, whether through **outright purchase** or **donation**, gives the new owner almost complete control over the land. This is the most effective conservation tool, but purchasing land is also the most expensive. Conservation groups such as The Nature Conservancy buy significant lands when funds allow or other methods of conservation are unsuitable. Occasionally, colleges and universities receive gifts of land that have significant ecological value and retain them as open space or research areas (Worley and Klein 1980).

Conservation easements are basically negative rights. Instead of selling or donating acreage, the landowner gives up certain rights to the land in return for tax breaks or other incentives. The type of easement varies between organizations, as does the length and stipulations. In bogs, actions which obviously disrupt the ecosystem, such as road building, would be strictly prohibited. On the other hand, firewood was harvested selectively off Dickerman Bog for several winters with no discernible impacts, and may be allowed under certain easements.

Government agencies can protect land through **regulating** land use. Worley and Klein (1980) point out that regulations are usually passed to control development rather than preserve natural areas. Water quality laws, zoning, and agricultural district designations are examples of regulations, and are often unpopular with landowners.

Private stewardship, in a sense, is the unsung hero of peat bog conservation. Although most bogs in Minnesota are state-owned (Malterer 1980), a fair proportion are owned by landowners who have preserved the integrity of their bogs through active conservation or passive acceptance. In his land ethic, Aldo Leopold (1949) writes:

> It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value. By value, I of course mean something far broader than mere economic value; I mean value in the philosophical sense.

Several tools can be used to lift landowners to this new level of ecosystem awareness (Worley and Klein 1980). Inventories bring bog ecology out of the fog and into focus, making landowners more aware of the diversity in their bogs. Informing and educating landowners of the ecological processes and species dependence in bogs is possible through public and private agencies at all levels. Landowner contact programs notify landowners of significant aspects of their peatlands, and explain the ecological value of such characteristics.

While private stewardship of a peat bog may be a noble cause, it still does not remove the burden of ownership. Unfortunately, other options for bog owners offer little encouragement. In this sense, Dickerman Bog may be painfully representative of many Minnesota bogs. Efforts to compile a list of agencies and organizations interested in conserving Dickerman Bog yielded only limited success.

Organizations such as **The Nature Conservancy**, **Audubon Society**, and **Ducks Unlimited** focus their limited resources toward conserving endangered species and ecosystems (Janet Green, Robert Meeks, and Lisa Muehler, pers. comm.). A large number of Minnesota bogs do not meet such requirements. Conservation organizations are forced by limited budgets to prioritize habitats by threat, and unless an endangered or threatened species is present in the bog, conservation organizations cannot justify spending the funds to buy outright or administrate over a conservation easement.

Registering a parcel of land as a natural area with The Nature Conservancy remains an option for the landowner who wishes to make some sort of formal gesture of conservation. The owner agrees in good faith to preserve the land, without benefit of a legal contract, tax breaks, or incentives. The land, if sold, is not bound by any sort of contract, and the new owner can break the agreement.

The **Minnesota Scientific and Natural Areas** program provides the highest possible degree of protection to preserved lands within the state. Owners can deed land to the program, provided the land has some sort of ecological significance. Because the easement is enforced by conservation officers and other natural resource personnel, the state cannot afford to accept land that does not play an important role in preserving rare species, landforms, or ecological values.

Counties participate in the preservation of peatlands by lowered assessments on wetlands. In **St. Louis County**, the per acre tax on developed upland approximates $300-480. The tax on bog acreage is about $50/acre. In areas where urban development is advanced, undeveloped land can be assessed as "green space" (Janet Green, pers. comm.). This results in lower yearly taxes for the owner, but it is doubtful whether or not such tax breaks deter landowners from subdividing or selling the land to a developer. In northeastern Minnesota, where nearly all of Minnesota's peat deposits lie, only Duluth's population exceeds 50,000 (Saari and Dupuis 1990), and "green space" is not considered to be a necessity for the resident's quality of life.

Like the state, St. Louis County will not accept gifts of land that have little ecological significance (Jerry Murphy, pers. comm.). The common, undesirable, practice of forfeiting land to the county through nonpayment of taxes does not necessarily result in conservation. After forfeiture, the county is free to lease the land to developers, subject to the approval of the commissioner of natural resources (MN DNR 1987).

The **Fond-Du-Lac Indian Tribe** in northern Minnesota expressed a willingness to accept a donation of a peat bog (Henry Buffalo, pers. comm.). Federally recognized Indian tribes across the country can accept gifts of land, without paying taxes on the acreage. The actual conditions of the donation would be subject to discussion, but would result in perpetual preservation.

Colleges and universities oftentimes own real estate, but usually land gifts are sold to boost the school's financial budget (Lance Cavanaugh, Richard Weiland, pers. comm.). Because peat ecology programs were not currently included in either school's curriculum, the **University of Minnesota, Duluth** and the **College of St. Scholastica** declined to accept the donation of a bog with the stipulation that it be conserved. The University, through its research arm the Natural Resource Research

Institute (NRRI), operates a peat program, but the NRRI already has available to them a large peatland complex. The university, though it is not required to pay taxes on its real estate holdings, does pay taxes as a good will measure. Land that cannot be sold to enhance academic programs is merely a drain on their finances.

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5 August 1990

Good grief. You can't even give away a peat bog in this state. And the frustrating thing about it is that other people's ambivalence is rubbing off on me. So what if someone fills in this bog? It's practically worthless. As close to the proverbial wasteland as one can get. We might as well drain it, top it off with gravel, and make a go-cart track out of it. Then we could at least charge money to use it.

But I know that there is something special here. I can sense it when I sit silently in the center of the bog. It closes in around me, whispers to my frazzled senses, envelopes me in a world of solitude. Someone said once that when you want to get away from it all, "you go to a peat bog." Perhaps this place is so special because it is the last outpost of remoteness. No one disturbs me here. This may be the only place the "real world" can't conquer.

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Seeking out groups to direct the conservation of rather ordinary, rather common peat bogs proved to be a convoluted search. The lack of significant species or landforms in ombrotrophic bogs is not likely to change, nor are the underfunded budgets of conservation groups or agencies. The future of bog conservation, then, lies with landowners. In this age of expanded government and service professions, we automatically look elsewhere for assistance and guidance, but in all likelihood, the preservation of privately-owned bogs will come about through renewed awareness of stewardship and initiative. This land ethic that so excited Aldo Leopold begins with a firm grasp of ecological principles and an understanding of the intricate biosphere we live in.

Bogs symbolize, perhaps more effectively than any other ecosystem, the interconnected, complex web that supports life. The soil that supports bog vegetation alters the water regime and is in fact the accumulation of a thousand years of plant remains. The water impedes decomposition and dictates very precisely the type of vegetation that contributes to the soil. Mosses transform the topography and determine the source of nutrients that nourish the trees and shrubs. Birds that spend winters in tropical, gentle climates flock to the unique conifer forests of the harsh north when spring warms the dormant landscape. Few events happen in isolation. The drainage of peat soils in northern Minnesota reverberates, somehow, to the small warblers that perch in the waving palm trees of southern Florida. To lose even a single acre of habitat, a single species, a single peat bog influences us more than we know, or can try to comprehend. Eventually, though, we learn the consequences of our actions. What we lose, and do not notice, in our day to day bustle must necessarily resurface in our long-term, retrospective memory.

Odd to think that the mysterious, isolated peat bog can affect the quality of life we so highly value. Some things never cease to amaze.

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