A RECORD OF THE NATURAL HISTORY AND ANTHROPOGENIC SENESCENCE OF AN INDIANA TAMARACK BOG

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Abstract: The development of Tamarack Bog, Noble County, Indiana, began in a clay-lined kettle depression associated with an historic lake. The stratigraphy of the sediments suggests that development of the peatland plant community was not a result of the recent drainage (*circa* 1850) of the lake as was previously thought; rather, peatland formation was a natural process initiated after Wisconsin glaciation. Based on subfossil remains, analysis of tree growth rings, reports of early 20th-century botanists, and present vegetation, the drainages accelerated the senescence of the bog community, resulting in a transition from an open *Sphagnum* bog with stunted tamarack, to a tamarack forest, and finally, to a red maple swamp. The remnant bog community is situated over the deepest subbasin in the bog due to inundation and high acidity caused by variable subsidence of the peat. The forest canopy limits growth of the heliophilic bog plants by shading. A restoration attempt has been initiated.

KEYWORDS: Amoebae, bog, chrysophyte, fen, *Larix*, paleoecology, peatland, restoration, *Sphagnum*, subfossil.

INTRODUCTION

Thirty percent of the original 16,307,851 ha of wetlands in the United States has been lost as a result of anthropogenic disturbance (Dahl, 1990). Most of these losses were caused by drainage. In the Midwest, such drainage was often conducted to yield fertile land for agriculture. Indiana, having lost 87% of its original wetland coverage, ranks forty-sixth in the nation for remaining wetlands (Dahl, 1990). A significant portion of the wetland lost was peatland. Although most of the peatlands in the United States occur in the Northeast and in the northern Lake States, data compiled from U.S. Department of Agriculture soil surveys show that Indiana once harbored over 62,000 ha of peatland; approximately 66%, or 41,000 ha, has been drained (Swinehart, in prep). The majority of Indiana's remaining peatlands are small, isolated relics from earlier times when natural and anthropological factors were more favorable to their establishment and development.

The loss of a large portion of Indiana's natural peatland communities coupled with the rapid senescence and destruction of the remainder demands that their unique ecology be recorded before the existing representatives vanish. A study of these communities in Indiana may help characterize their late successional stages, because these wetlands have been exposed from glaciation longer than the

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peatlands of the far north. Their occurrence at the southern boundary of the range of the northern bog community results in unique floral communities with mixed geographic affinity (Crow, 1969; Swinehart, 1994). Despite the need for detailed research, only a limited number of studies have been conducted on the ecology of Indiana's peatlands (see Markle, 1916; Potzger, 1934; Hull, 1937; Wilcox, 1982, 1988; Wilcox, *et al.,* 1986; Swinehart, 1994, 1995a). New or additional records of the pre-settlement and current ecology of Indiana peatlands as well as documentation of the effects of human disturbance on these communities may facilitate conservation and restoration strategies.

The present study documents the natural history and ecological development of Tamarack Bog, a drainage-induced senescent *Sphagnum* bog located in northern Indiana. The objectives for the present paper are to: 1) determine the factors that favored the formation of the bog; 2) reconstruct its development from the time of glacial retreat to the present; 3) describe the effects of drainage on the ecosystem; and 4) outline methods to restore a small portion of the community to its pre-drainage condition.

STUDY AREA

Tamarack Bog (Section 7, Noble Township, Noble County, Indiana) occurs within the boundaries of the Merry Lea Environmental Center, a 600 ha nature preserve owned and operated by Goshen College. This location (Figure 1) is within a physiographic unit called the Northern Moraine and Lake Region (Schneider, 1966). Most of the lakes and water-filled depressions in the area are kettles that were created at the interstice of the Saginaw and Erie Lobes of Late Wisconsin glaciation.

The study area was first mapped by the United States General Land Office in 1829. The bog itself was first noted by Dryer (1901). Alton A. Lindsey conducted the first survey of the conspicuous vegetation in 1972 (unpubl. field notes).

Gradual invasion of the bog by shade-tolerant trees, primarily *Acer rubrum, Acer saccharinum,* and *Quercus palustris,* has confined the remnant bog species to a small wet depression (10,500 m^2) near the center of the wetland basin (375,000 m^2). The only evidence of the previous *Larix laricina* forest is the remains of hundreds of dead trees.

The entire system is surrounded by topographically high glacial features (Figure 1). Its western border is an extensive esker; its northern, a pitted esker-delta; and its eastern, a gravel ridge (Dryer, 1901). The north shore of High Lake forms the southern boundary of the wetland. Several other peatlands, associated with the complex glacial topography, occur in the immediate vicinity (Swinehart, 1994).

MATERIALS AND METHODS

Vegetation. Frequency and cover percentages for the vegetation were obtained using systematically placed quadrats. Importance values (I.V.) were calculated by summing the relative frequency and relative cover for each species and dividing by two. The primary sampling area was defined as the area

Figure 1. A map of the study area showing the extent of Old Bear Lake, the current lakes, and the locations of Tamarack and Lost Bogs.

containing conspicuous remains of *Larix laricina*. This definition seemed to best represent the remnant bog community. The vegetation was also sampled outside of the boggy portion. A baseline was established in a west-east orientation across the center of the entire wetland basin. Within the primary sampling area, transects were established perpendicular to the baseline at 20 m intervals. Quadrats were placed at 15 m intervals along each transect. Herbaceous and ground layer species were sampled using 1 m^2 quadrats; shrubs were sampled using 100 m^2 quadrats. Thirty-nine quadrats were sampled in the primary sampling area, and 28 quadrats were sampled in the surrounding wetland. The vegetation was stratified on the basis of height. Plants over 3 m comprised the tree layer, plants between 1 and 3 m comprised the shrub layer, plants less than 1 m comprised the herbaceous layer, and plants forming the substrate or those directly associated with it comprised the ground layer.

Frequency of "bog plant" species (Figure 3) was calculated from three transects that extended across the entire wetland. Bog plants were defined as those species which occurred in the boggy portion of the wetland (Table 2).

Voucher specimens of the vascular plants are held by the herbarium at Central Michigan University (CMC) and in the private herbarium of A.L. Swinehart. Bryophytes are held by A.L. Swinehart and the University of Michigan Herbarium (MICH).

Microorganisms. Randomly selected pools of standing water in the bog were sampled for microorganisms. Samples were taken to the laboratory immediately after collection, where the microorganisms were recorded on videocassette for identification. A portion of each sample was fixed with Acid Lugol's solution. These samples were prepared for Transmission Electron Microscopy (TEM) of the silica-scaled chrysophytes. TEM analysis and micrography were conducted by the primary author.

Basin Morphometry and Stratigraphy. A metal probe was used to determine the depth of the sediments along several transects covering the entire wetland basin. Probing sites were systematically spaced at 20 m intervals along each transect. An auger tip at the end of the probe was used to collect samples of the hardpan. A Hiller core-sampler was used to collect peat samples at 50 cm intervals in the deepest subbasin of the peatland. Peat samples were refrigerated between collection and analysis to limit decomposition. Samples were washed through a 0.5 mm screen, and the subfossils were sorted and identified. Voucher specimens are held by the primary author.

Water. Water samples collected from pools of standing water occurring along the baseline were tested for pH and conductivity using a Cole-Parmer digital pH meter and a YSI Model 33 conductivity meter.

RESULTS AND DISCUSSION

History. Tamarack Bog was thought to have originated on acidic sediments exposed by the drainage of a lake (Larry R. Yoder, pers. comm.). An unpublished map, drawn in 1972 by Alton A. Lindsey, showed the outline of a 400 ha lake which covered what is currently Tamarack Bog. The outline was based on the original U.S. General Land Office map of Bear Lake from 1829 (hereafter referred to as Old Bear Lake). Careful study of the contour intervals drawn from recent airphotos suggests that the original lake occurred farther south than Lindsey had placed it. A revised map of the lake (Figure 1) indicates that Tamarack Bog was not covered by open water at the time of drainage (*circa* 1850); rather, the bog was probably a semi-buoyant mat of bog vegetation occupying a bay on Old Bear

Lake prior to its drainage. This interpretation is supported by the paleoecological data discussed below.

Basin Morphometry and Hardpan Composition. The deepest subbasin in the peatland has a depth of 10 m. This deep portion is surrounded by a broad, shallow rim and is connected to the High Lake basin by a deep, narrow trough (Figure 2). The entire wetland basin is lined with clay which limits circulation between the basin and the mineral-rich groundwater (Dansereau and Segadas-Vianna, 1955). Poor drainage coupled with small size, shelter from wind erosion, and wind/wave induced mixing (provided by the surrounding physiography) contributed to peatland formation by reducing the availability of oxygen and nutrients.

Paleoecology. Sediments between the depths of 2.5 and 8.5 m from the surface contained variable amounts of marl (complexed with organic material), aquatic plant remains (primarily *Najas flexilis* and sedges), mollusk shell-fragments, and the spicules of freshwater sponges (*Anheteromeyenia* spp.). The composition and thickness of this assemblage suggests that open water persisted in the basin for thousands of years. At depths between 5.5 and 2.5 m from the surface, brown mosses (family Amblystegiaceae) dominate the subfossil assemblage. *Calliergon trifarium* was the dominant peat-forming moss, and *Meesia triquetra* was an uncommon associate (Swinehart, 1995b). Both are boreal relics indicative of mineral-rich peatlands (Howard A. Crum, pers. comm.). The abundance of these calciphilic mosses suggests that a mineral-rich peatland was associated with the basin. Their occurrence within marl, along with the presence of sedge remains, suggests open-water surrounded by a marginal mat of peat-forming vegetation. Such a mat has already reformed, since the drainage, on the west side of High Lake. Detritus from the peatland margin probably washed into the deeper parts of the open-water basin and mixed with the marl that resulted from planktonic photosynthesis.

Two major changes in the peatland are indicated by changes in the sediments starting at a depth of 2.5 m. First, the establishment and eventual dominance of *Sphagnum* starts at this level. Second, the marl disappeared from the sediments. These two changes suggest the closure of open water which probably facilitated *Sphagnum* establishment by reducing circulation with mineral-rich lake waters. Initially, *Sphagnum* peat and *Calliergon* peat were deposited simultaneously, as conditions were favorable for the two species only in localized microhabitats (mineral-poor and mineral-rich, respectively). However, peats between the surface of the bog and a depth of 0.5 m mark the disappearance of the brown mosses and are composed almost entirely of *Sphagnum.*

The stratigraphy and composition of the sediments in Tamarack Bog imply a gradual development from open-water lake conditions, to a marginal mat of sedges and fen mosses, to closure of open-water, and, finally, to the development of a *Sphagnum* bog community. Contrary to previous hypotheses, the bog community was not created recently on acid sediments following drainage. Rather, drainage simply accelerated the senescence of a wetland that had been developing since the recession of the Wisconsin glacier.

Drainage. The exact time of the first drainage of Old Bear Lake is not known, but estimates place it *circa* 1850. This initial drainage left three smaller lakes

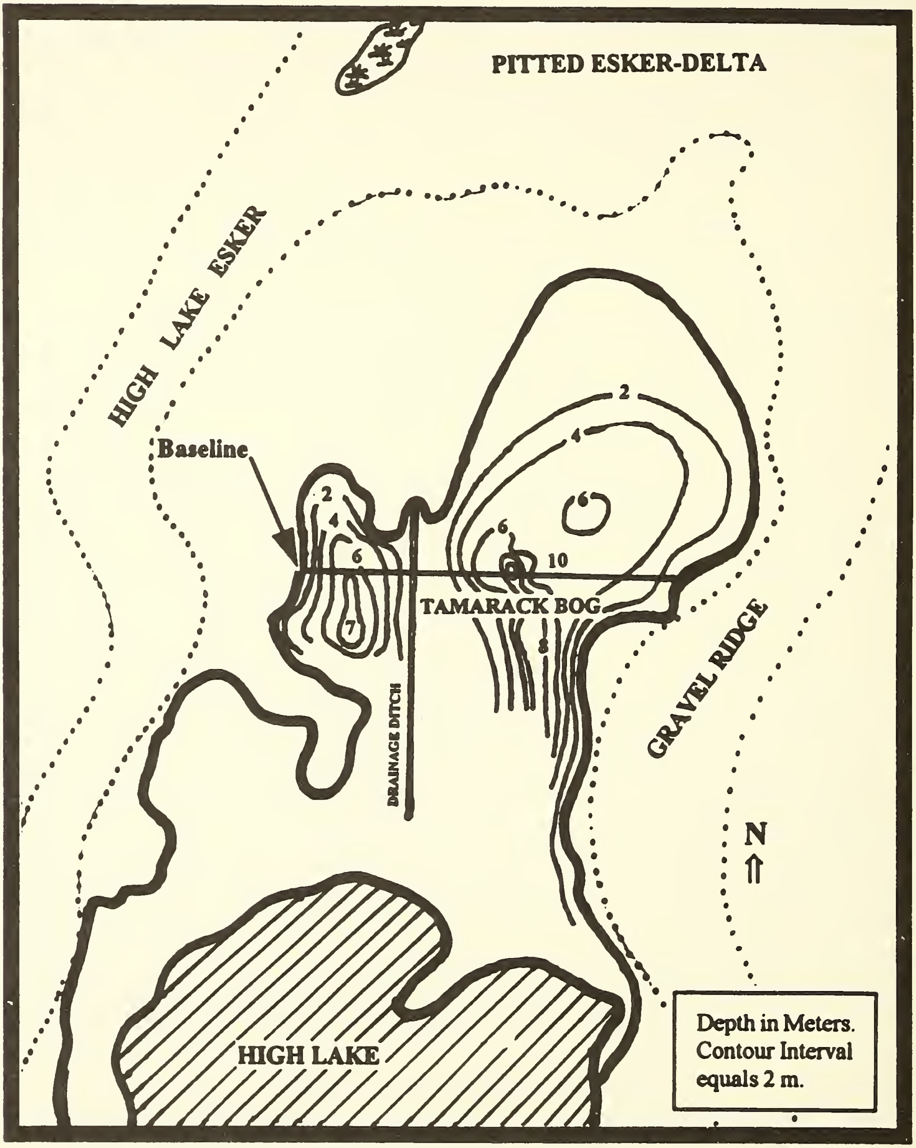

Figure 2. A map of Tamarack Bog showing its depth contours and the surrounding glacial features.

(Dryer, 1901): Bear Lake (190 ha), High Lake (136 ha), and Greater Cub Lake (~ 20 ha). A second drainage occurred in the fall of 1899 (Blatchley and Ashley, 1901), reducing the lakes to their current size (Figure 2): 56 ha, 45 ha, and 5 ha (with Little Cub Lake at ~ 1 ha), respectively. The drainages were implemented to provide tillable land for farming. However, the poorly-drained, acidic peats

Table 1. The dominant vegetation of Lost Bog.

Acer rubrum	red maple
Acer negundo	box elder
Ambrosia trifida	giant ragweed
Carex spp.	sedges
Cornus stolonifera	red-osier dogwood
Crataegus sp.	hawthorn
Fraxinus pennsylvanica	green ash
Impatiens capensis	spotted jewelweed
Parthenocissus quinquefolia	Virginia creeper
Phalaris arundinacea	reed canary grass
Prunus serotina	wild black cherry
Populus tremuloides	quaking aspen
Rhus typhina	staghorn sumac
Rosa multiflora	multifloral rose
Salix sp.	willow
Solidago spp.	goldenrods
Spiraea sp.	meadowsweet
Ulmus americana	American elm
Urtica procera	tall nettle
Vitis riparia	river grape

provided by the drainage were suitable for only a few crops (potatoes, onions, and peppermint). Some of the peripheral mucks were suitable for corn, soybeans, wheat, and alfalfa.

Before the second drainage was conducted, Dryer (1901) noted the presence of two "tamarack swamps": Tamarack Bog north of High Lake and Lost Bog on the northwest end of Bear Lake (Figure 1). Tamarack Bog has experienced little disturbance in the form of cutting; however, a drainage ditch was excavated within the wetland in the late 1930s (Phil Goodrich, pers. comm.). Since little other disturbance has occurred, the effects of overall drainage on the bog could be studied. Lost Bog was also ditched, and, in addition, the forest was completely removed by humans. The flora of Lost Bog is now typical of the flora of disturbed wetlands (Table 1).

Effects of Drainage. Effects of drainage on the ecology of Tamarack Bog are represented in the annual growth rings of the necrose tamarack trees. Cross-sections taken at the estimated breast height of trees buried in the peat (representing the oldest trees) exhibit clear changes in their annual growth rings. An abrupt change from narrow rings (mean 2 cm radius = 50 years) to wider increments (mean 2 cm radius = 16 years) indicate a drastic and immediate response to drainage. Fallen tamarack of moderate condition (representing middle-aged remains) show wide, evenly spaced growth rings throughout (mean 2 cm radius = 7 years). Standing dead trees with attached bark (representing recent trees) show wide, evenly spaced rings followed by gradually narrower rings (mean 2 cm radius = 22 years) just before death. Currently, only three tamaracks survive in the bog.

Since Tamarack and Lost Bogs both occurred in secluded bays on Old Bear Lake, drainage should have had similar effects on both ecosystems. No tamarack remains occur in Lost Bog. However, log cabins built from tamarack taken from the bog (*circa* 1917) exist near Bear Lake, and cross sections of their logs were

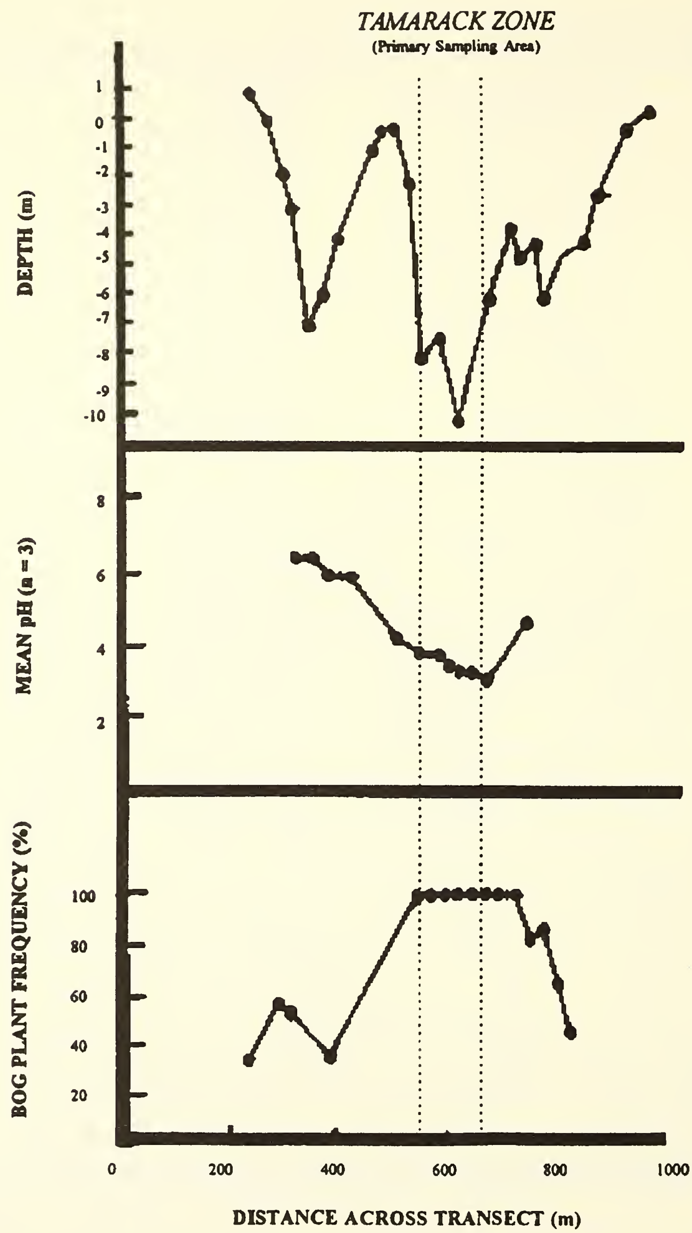

Figure 3. Depth, pH, and bog plant frequency along a west-east transect bisecting the basin of Tamarack Bog.

obtained. Sections taken from the butt-end of the logs showed identical ring-sequences to those of the oldest trees in Tamarack Bog. The point at which the growth rings changed from highly condensed rings to more widely spaced rings averaged 20 years prior to the cutting of the tree. This transition coincides with the second and likely most destructive drainage of the watershed in 1899.

Table 2. The percent frequency, percent cover, and importance values (I.V.) for the vegetation in Tamarack Bog.

Layer/Species	Frequency (%)	Cover (%)	I.V.
Shrub Layer			
Vaccinium corymbosum	21	5	4
Ilex verticillata	16	3	3
Lindera benzoin	13	2	2
Aronia melanocarpa	11	1	1
Prunus serotina	11	1	1
Toxicodendron vernix	5	< 1	< 1
Acer spp.	3	1	< 1
Amelanchier laevis	-	-	-
Nemopanthus mucronatus	-	-	-
Herbaceous Layer			
Maianthemum canadense	97	24	20
Trientalis borealis	89	7	9
Osmunda cinnamomea	73	6	8
Acer spp.	86	3	7
Rubus hispidus	56	6	7
Dryopterus spinulosa	27	1	2
Prunus serotina	22	1	2
Rubus allegheniensis	16	1	1
Parthenocissus quinquefolia	13	1	1
Quercus palustris	13	1	1
Vaccinium corymbosum	11	1	1
Lindera benzoin	11	1	1
Ilex verticillata	8	< 1	< 1
Bidens sp.	5	< 1	< 1
Aronia melanocarpa	3	< 1	< 1
Cypripedium acaule	-	-	-
Lycopodium lucidulum	-	-	-
Lycopodium obscurum	-	-	-
Ground Layer			
Pallavicinia lyellii	76	5	7
Tetraphis pellucida	30	2	3
Aulacomnium palustre	40	1	3
Lophcolia heterophylla	27	< 1	2
Callicladium haldanianum	24	1	2
Sphagnum recurvum var. *tenue*	3	2	1
Mnium cuspidatum	13	< 1	1
Plagiothecium denticulatum	13	< 1	1
Rhynchostegium serrulatum	5	1	< 1
Thuidium delicatulum	5	< 1	< 1
Sphagnum palustre	2	< 1	< 1

Drainage of the bogs resulted in an increased availability of oxygen and nutrients that caused the increased growth of the tamarack, especially after the second drainage. Following the drainage of Tamarack Bog, the forest continued to grow until competition for light with newly established competitors (primarily *Acer rubrum* due to the improved soil conditions) stifled growth and eliminated all but three of the tamarack. Such a transition from *Larix* to *Acer rubrum* occurs naturally in all tamarack bogs in Indiana (Swinehart, in prep). Tamarack are opportunists and colonize areas where competition for light is minimal (Duncan, 1954). In the southern portions of its range, tamarack survives in hydric conditions until, as the site becomes more mesic, it is overtaken by shade-tolerant arborescent species (Deam, 1940). LeBarron and Neetzel (1942) concluded that the drainage of bogs accelerates the growth and production of hardwood trees that eventually replace the conifers. Their conclusion is supported by the changes documented at Tamarack Bog.

Drainage-induced senescence in Tamarack Bog led to drastic changes in the plant community in less than 80 years. Several plant species that are indicative of open bog communities were noted by early 20th century botanists. Charles Deam reported *Andromeda glaucophylla* (bog rosemary) in 1920 (Indiana Department of Natural Resources, 1992), and Ray Friesner reported *Sarracenia purpurea* (purple pitcher plant) and *Vaccinium oxycoccos* (small cranberry) in 1935 and 1938, respectively (Indiana Department of Natural Resources, 1992). The present study confirms the reports of *A. glaucophylla* and *Vaccinium* sp. (cranberry) through the recovery of leaf subfossils embedded in the surface peats of the bog. In addition, subfossils of *Chamaedaphne calyculata* (leatherleaf) leaves were recovered. These species are typical of open *Sphagnum* bogs. Dryer (1901), Blatchley and Ashley (1901), Deam, and Friesner all reported extensive stands of tamarack and characterized the community as a tamarack swamp or tamarack bog. All of these plants, except for a few tamarack, have now died out in the bog.

Prior to this study, the only recent floral survey of Tamarack Bog was conducted in 1972 by Alton A. Lindsey (unpubl. field notes). He reported the presence of *Vaccinium macrocarpon* (American cranberry) and *Cypripedium acaule* (pink lady's slipper) among other common bog plants. At the time of Lindsey's visit, only 25-30 living tamarack remained.

Currently, *Vaccinium macrocarpon* has been extirpated in the bog, and tamarack has been reduced to three living individuals. The numbers of *Cypripedium acaule* have remained stable (Swinehart, 1994). Lindsey (pers. comm., 1993) stated that the canopy of the *Acer rubrum* forest had almost completely closed since his observations in 1972, when the bog was relatively open. The transition to a forest dominated by *Acer rubrum* has resulted in a decrease in the number of bog species, including *Sphagnum,* and an increase in the number of more common swamp species (Swinehart, 1994).

The dense canopy of red maple limits the understory flora to shade-tolerant species. In addition to shade-tolerance, plants in the bog must also be tolerant of saturated soils and extremely low pH and conductivity. Values for pH ranged from 3.5 to 4.3 within the tamarack zone and between 3.5 and 6.3 in the surrounding wetland (Figure 3). Conductivity was 45 μMHOS. Many of the plants

Table 3. The percent frequency, percent cover, and importance values (I.V.) for the vegetation in the wetland surrounding Tamarack Bog.

Layer/Species	Frequency (%)	Cover (%)	I.V.
Shrub Layer			
Vaccinium corymbosum	8	2	2
Ilex verticillata	8	1	1
Aronia melanocarpa	5	1	1
Lindera benzoin	5	1	1
Acer spp.	3	< 1	< 1
Cornus foemina	3	< 1	< 1
Rhamnus alnifolia	3	< 1	< 1
Herbaceous Layer			
Impatiens capensis	35	11	14
Maianthemum canadense	73	6	12
Rubus hispidus	57	6	11
Acer spp.	59	2	8
Rubus allegheniensis	35	3	7
Dryopterus spinulosa	41	2	6
Trientalis borealis	38	2	6
Osmorhiza claytonii	16	2	4
Ilex verticillata	16	1	3
Osmunda cinnamomea	16	1	3
Aronia melanocarpa	16	< 1	3
Toxicodendron radicans	14	1	2
Viola spp.	14	1	2
Prunus serotina	14	< 1	2
Galium spp.	11	1	2
Smilacina racemosa	8	< 1	1
Urtica procera	8	< 1	1
Arisaema triphyllum	5	1	1
Onoclea sensibilis	5	< 1	< 1
Thelypterus palustris	5	< 1	< 1
Fraxinus pennsylvanica	3	< 1	< 1
Quercus palustris	3	< 1	< 1
Ranunculus recurvatus	3	< 1	< 1
Rosa palustris	3	< 1	< 1
Ulmus americana	3	< 1	< 1
Osmunda regalis	-	-	-
Ground Layer			
Pallavicinia lyellii	32	1	4
Mnium cuspidatum	22	1	3
Lophcolia heterophylla	14	< 1	2
Thuidium delicatulum	11	1	2
Aulacomnium palustre	3	< 1	< 1

Table 4. The microorganisms and aquatic macrofauna of Tamarack Bog.

Microflora	Microfauna	Macrofauna
Bacillariophyta	**Sarcodina**	**Amphibia**
Achnanthes sp.	*Acanthocystis* sp.	*Pseudacris crucifer*
Diatoma sp.	*Actinosphaerium* sp.	*Rana clamitans*
Eunotia sp.	*Amoeba* sp.	*Rana sylvatica*
Navicula sp.	*Arcella* sp.	
Pinnularia sp.	*Difflugia* sp.	
	Nebela sp.	
Chrysophyta	**Ciliophora**	
Chrysosphaerella sp.	*Spathidium* sp.	
Mallomonas calceolis	*Spirostomum* sp.	
Synura petersenii		
Euglenophyta	**Rotifera**	
Euglena arcus	*Monostyla* sp.	
Eutreptia viridis		
Chlorophyta	**Platyhelminthes**	
Ulothrix sp.	*Stenostomum* sp.	
Unidentified coccoid		
	Crustacea	
	Cyclops sp.	
	unidentified isopod	
	unidentified orbatid mite	
	Insecta	
	Celina sp.	
	unidentified mosquito larvae	

that can survive in these conditions are bog plants that require full sunlight. The low light conditions in Tamarack Bog coupled with the acidic, saturated soil may account for the relatively low number of species and sparse subcanopy cover. These conditions may also account for the recent extirpation of pitcher plant, cranberry, bog rosemary, and leatherleaf.

Extant Flora. Twenty-six vascular plants and 12 bryophytes were found within the primary sampling area (Table 2). Many of these species are remnant bog species. *Vaccinium corymbosum* (high-bush blueberry) and *Ilex verticillata* (winterberry holly) dominate the shrub layer. *Toxicodendron vernix* (poison sumac), *Aronia melanocarpa* (chokeberry), and *Nemopanthus mucronatus* (mountain holly) are poorly represented, probably due to shading. Decadent tamarack bog species in the herbaceous layer included *Maianthemum canadense* (Canada mayflower), *Trientalis borealis* (starflower), *Osmunda cinnamomea* (cinnamon fern), *Rubus hispidus* (northern raspberry), *Cypripedium acaule, Lycopodium lucidulum* (shining club moss), and *Lycopodium obscurum* (running ground pine).

Although several bryophytes occupy the ground layer (Table 2), only four taxa grow directly on exposed peat: *Sphagnum palustre, S. recurvum* var. *tenue, Aulacomnium palustre,* and *Pallavicinia lyellii.* All are acidophiles common to bogs. *Sphagnum palustre* grows on saturated peat in the bog, while *S. recurvum* is more common in wet or inundated depressions. *Pallavicinia lyellii* is unusually abundant and is the dominant bryophyte throughout the bog, growing on exposed peat hummocks and protruding tamarack stumps. The dominance of *P. lyellii* is characteristic of old tamarack bogs in Indiana (Swinehart, in prep).

The remnant bog community is situated directly over the deepest portion of the basin, which has a maximum depth of 10 m (Figure 3). Its position seems related to the water-level dynamics caused by drainage. The semi-flocculant, inundated peat began to compress as water levels were lowered. This subsidence created dimples in the surface of the peatland that remained inundated and consequently more resistant to invasion by typical swamp species due to high acidity, low oxygen, and a dearth of available nutrients. Based on the elevation of Old Bear Lake (approximately 903 ft (Dryer, 1901)) and the current elevation of the bog (900 ft), the surface of the peatland subsided as much as one meter. Subsidence was proportional to the volume and density of the peat within the respective subbasins. Differential subsidence may account for the patches of inundated peat and the occurrence of the most conspicuous remnant bog communities being situated over the deepest portions of the basin (Figure 3). The surrounding areas are drier and have a flora more characteristic of a swamp (Table 3). Tamarack remains in these peripheral areas exist only as weathered stumps and rootstocks.

Microorganisms. Microorganisms in the waters of Tamarack Bog are indicative of acidic conditions. Acidophilic testate and atestate amoebae were represented by six taxa (Table 4). Silica-scaled chrysophytes were poorly represented: *Mallomonas calceolis* is indicative of dystrophic waters, and *Synura petersenii* is found in a wide range of water conditions (Wujek and Swinehart, 1995). Desmids, which are normally common in bog waters, were absent, although nearby *Sphagnum* bogs harbored a diverse community (Swinehart, 1994). The lack of desmids in Tamarack Bog is attributed to the low light intensity.

Fauna. Aquatic animals were limited to species tolerant of low-oxygen, acidic conditions where primary productivity is extremely limited (Table 4). The most common arthropods in the stagnant pools were dytiscid beetles (*Celina* sp.), isopods, and mosquito larvae. Several species of mature anurans were noted in the bog, but no larvae were found inhabiting the bog waters.

Restoration. Restoration of a small portion of Tamarack Bog has been initiated. A 400-m^2 plot was established around two of the three remaining tamarack. Thirteen permanent quadrats (1 m^2) were established for sampling the herbaceous vegetation within the plot. Four 100-m^2 quadrats were established to sample the shrubs. Frequency, cover, and importance values (as well as density and diameter at breast height for the trees) were obtained for the vegetation before all the trees and shrubs were removed from the plot.

Several changes have been noted after one year. The substrate in the plot, which was previously devoid of *Sphagnum,* has been colonized by large patches of *Sphagnum palustre* (31% by frequency; 3% by cover). *Carex trisperma* (a rare bog sedge in Indiana) has formed extensive lawns, although previously it was not found within the plot. Plantings of *Vaccinium macrocarpon* from a nearby bog have been successful, and significant vegetative expansion has since occurred.

Initial observations on the study plot have shown that removal of the sapric peat that overlies the fibric peat limits the growth of swamp shrubs and favors *Sphagnum* and other bog plants. Removal of the remainder of this layer is planned, and the subsequent viability of prospective seed banks will be examined. The mitochondrial DNA of prospective introductions will be compared to that of the subfossils in the peat to insure the genetic integrity and evolutionary viability of the system. The plot will continue to be monitored on an annual basis.

CONCLUSION

The relative rarity of bogs in Indiana justifies their preservation for conservational and educational purposes. These unique "southern" bog communities provide a rare educational resource for local citizens. Bogs are useful in teaching floral adaptations, ecological succession, and the relationships between glacial processes and existing ecosystems. Since Tamarack Bog occurs within the boundaries of the Merry Lea Environmental Center of Goshen College, a center providing environmental education programs for area residents, successful restoration of a small portion of the bog will provide an excellent and accessible educational resource that would otherwise be unavailable.

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