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The Drowned Lands' last stand: An inland Atlantic white cedar peat swamp in Orange County, New York

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KARLIN, E. F. (School of Theoretical and Applied Science, Ramapo College, Mahwah, NJ 07430). The Drowned Lands' last stand: An inland Atlantic White cedar peat swamp in Orange County, New York. J. Torrey Bot. Soc. 124: 89–90. 1997.—The vegetation of the only known remnant of what was once one of the largest inland Atlantic white cedar peat swamp complexes in the world (the Drowned Lands of Orange County, New York) is documented. Although logging and drainage have significantly affected this wetland, a small portion of the cedar swamp has remained somewhat intact. It is the southernmost locality for *Sphagnum contortum* K. F. Schulz, *S. quinquefarium* (Braithw.) Warnst., and *S. wulfianum* Girg. in New York. This community type is critically imperiled in both New York and New Jersey.

Key words: Atlantic white cedar, Drowned Lands, inland Atlantic white cedar peat swamp, larch, peatland, Wallkill River Valley, wetland, *Chamaecyparis thyoides, Larix laricina, Sphagnum, Sphagnum contortum, Sphagnum wulfianum.*

A large (about 6880 ha) wetland complex known as the "Drowned Lands" (Eager 1846; Headley 1908) once flourished on the floodplain of the Wallkill River in Orange County, New York (in the Towns of Goshen, Minisink, Warwick, and Wawayanda). It also extended into the Town of Vernon in Sussex County, New Jersey and this portion presently forms the core of the Wallkill River National Wildlife Refuge. These wetlands had developed a thick (1–5 m) organic soil (Carlisle muck: mesic Typic Medisaprists [Olson 1981]) and occurred in the basin of what was once a large proglacial lake (Connally and Sirkin 1970).

Extensive white cedar swamps were one of the more prominent components of the Drowned Lands. Headley (1908) stated that they covered about 15,000 acres (6072 ha), which would have been about 88% of the Drowned Lands area in New York. Although this figure may be an overestimate, it does indicate that white cedar swamps were a significant part of the landscape. As the wood of white cedar was a valuable commodity (being used for construction, fencing, and making onion crates) many farmers in the region owned a wood lot in the Drowned Lands white cedar swamps in the late 1700s and early 1800s.

A number of settlements on small upland areas within the Drowned Lands were established in the 1700s, and at that time most were accessible primarily by boat (Eager 1846). Large scale drainage systems were established in the early 1800s and these lowered the regional water table in order to use the land for "black dirt" agriculture (Bicentennial Commission 1988), and allowed for road construction throughout the drained Drowned Lands region. Even though no longer surrounded by water, many Drowned Lands communities are still referred to as being islands (i.e., Pine Island).

By 1900, most of the natural vegetation of the Drowned Lands had been destroyed. In spite of the extensive drainage and agricultural development that had occurred, a few notable tracts of white cedar still remained at that time. However, even these few remaining white cedar swamps were drained and cleared in the following decades as it became economically viable to exploit more land for agricultural purposes. By the late 1970s it appeared that all of the white cedar swamps had been eliminated and that only a few isolated stands of hardwood swamp, occurring as islands in the midst of an extensive black dirt agricultural region, were all that remained of the once extensive Drowned Lands wetland complex.

Although the Drowned Lands white cedar swamps played a significant role in the history of Orange County, there does not appear to have been any botanical or ecological study of them. This is surprising, because all other major inland

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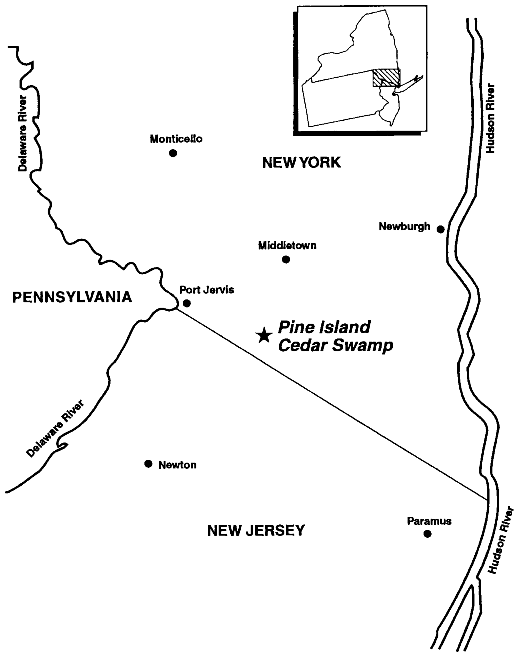

Fig. 1. Map of northern New Jersey and adjacent New York showing the location of the Pine Island Cedar Swamp.

Atlantic white cedar peat swamps in northern New Jersey and adjacent New York have been studied (Niering 1953; Montgomery and Fairbrothers 1963; Sipple 1971–1972; Belling 1977; Lynn 1984; Karlin 1997). There were not even any records indicating whether the cedar was Atlantic white cedar (*Chamaecyparis thyoides*) or northern white cedar (*Thuja occidentalis*). Both species naturally occur in Orange County, but neither the New York State Museum nor the New York Botanical Garden have any herbarium specimens documenting either species from the Drowned Lands.

Given their place in the history of Orange County and the fact that they were once ecologically significant ecosystems, it was imperative that some scientific documentation be made of the Drowned Lands white cedar swamps. With the help of local historians, naturalists, and farmers, I set out to discover what was known about these wetlands. Most of those that I spoke with believed that all of the cedar swamps had been destroyed. Some mentioned that a few cedar trees could still be found in the hardwood swamps associated with the few remaining undeveloped portions of the former Drowned Lands. And, indeed, I did find Atlantic white cedar in two such sites, one near Durlandville (Town of Goshen) and one near Pine Island (Town of Warwick). Much to my surprise, a tiny (about 1 ha) inland Atlantic white cedar peat swamp was also present at the Pine Island site (hereafter referred to as the Pine Island Cedar Swamp). It is surrounded by a hardwood swamp (about 84 ha in extent), which in turn is surrounded by farm fields with extensive drainage systems. Although the Pine Island Cedar Swamp is certainly not undisturbed, a small portion of it (about 0.1 ha) remains relatively intact.

Historical documents show that extensive cedar swamps were once present at both the Pine Island and Durlandville sites (manuscript collection of the Goshen Public Library and Historical Society, Goshen, New York). A map dated 1825 shows four "cedar swamp lots" (about 97 ha in extent) adjoining the parcel of land where the Pine Island Cedar Swamp occurs. Although highly drained black dirt farm fields now occupy the former "cedar swamp lots," local farmers say that cedar swamps still occupied much of the area as recently as 1920 and that the regional water table was much higher back then than it is at the present time. An extensive cedar swamp (about 175 ha) once occurred at the Durlandville site. It was surveyed, mapped and subdivided into 80 lots in the late 1700s by Samuel Gale. About one third of the cedar swamp had "good cedar lots" and the balance had "bad cedar lots." Although no survey data was available for the cedar swamp, there were survey notes from 40 "meadow lots" which were adjacent to the cedar swamp. Four types of trees were listed in this survey (cedar, black ash, maple, and pine), with cedar being named 21 out of the 31 times that trees were cited.

The objective of this study is to provide a quantitative description of the vegetation of the Pine Island Cedar Swamp (Fig. 1), which is the only known remnant of what was once one of the largest inland Atlantic white cedar peat swamp complexes in the world. This community type is now critically imperiled in both New York (Reschke 1990) and New Jersey (Tom Breden 1989).

Methods. A 0.1 ha (20 × 50 m) releve was established in the most intact portion (which was roughly 0.1 ha in extent) of the Pine Island Cedar Swamp. All vascular plant species in the releve were identified and assigned percent ground cover values (by cover classes: 5 = >75% 4 = 50–75%, 3 = 25–50%, 2 = 5–25%, 1 = 1–5%, + = less than 1%, R = much less

Table 1. Plant species occurring in a 0.1 ha plot in the Pine Island Cedar Swamp. Ground cover classes are assigned as follows: 5 = >75%, 4 = 50–75%, 3 = 25–50%, 2 = 5–25%, 1 = 1–5%, + = less than 1%, R = much less than 1%.

	Cover class		Cover class
Sphagnum	**3**	**Shrubs**	**5**
Sphagnum affine Ren. & Card.	2	*Vaccinium corymbosum* L.	4
Sphagnum fimbriatum Wils.	2	*Acer rubrum* (seedlings & saplings)	2
Sphagnum palustre L.	*	*Toxicodendron radicans* (L.) Kuntze	1
Sphagnum bartlettianum Warnst.	1	*Amelanchier canadensis* (L.) Medic.	+
Sphagnum girgensohnii Russ.	+	*Fraxinus nigra* Marsh. (saplings)	+
Sphagnum recurvum P. Beauv.	+	*Lindera benzoin* (L.) Blume	+
Sphagnum wulfianum Girg.	+	*Lyonia ligustrina* (L.) DC.	+
Other Mosses	**3**	*Rhododendron viscosum* (L.) Torr.	+
Aulacomnium palustre (Hedw.) Schwaegr.	2	*Rubus pubescens* Raf.	+
Hypnum imponens Hedw.	2	*Toxicodendron vernix* (L.) Kuntze	+
Leucobryum glaucum (Hedw.) Angstr.	2	*Ulmus americana* L. (saplings)	+
Thuidium delicatulum (Hedw.) Schimp.	2	*Chamaecyparis thyoides* (seedings)	R
Tetraphis pellucida Hedw.	1	**Herbaceous Plants**	**2**
Calliergon cordifolia (Hedw.) Kindb.	+	*Coptis trifolia* (L.) Salisb.	2
Dicranum montanum Hedw.	+	*Maianthemum canadense* Desf.	1
Dicranum flagellare Hedw.	+	*Osmunda cinnamomea* L.	1
Leptodictyum riparium (Hedw.) Warnst.	+	*Symplocarpus foetidus* (L.) Salisb. ex Nutt.	1
Climacium americanum Brid.	R	*Thelypteris palustris* Schott	1
		Dryopteris carthusiana (Vill.) Fuchs	+
Liverworts	**+**	*Impatiens capensis* Meerb.	+
Bazzania trilobata (L.) S. Gray	+	*Osmunda regalis* L.	+
Jamesoniella autumnalis (D.C.) Steph.	+	*Onoclea sensibilis* L.	+
Pallavicinia lyellii (Hook.) Carruth.	+	*Parthenocissus quinquefolia* (L.) Planchon.	+
Lichens	**n.a.**	*Trientalis borealis* Raf.	+
Punctelia subrudecta (Nyl.) Krog		*Viola macloskeyi* Lloyd	+
Lepraria lobificans Nyl.		*Aralia nudicaulis* L.	R
		Arisaema triphyllum (L.) Schott ex Schott & Endl.	R
Trees	**5**	*Gaultheria procumbens* L.	R
Chamaecyparis thyoides (L.) BSP.	4	*Clintonia borealis* (Aiton) Raf.	R
Acer rubrum L.	2	*Mitchella repens* L.	R
Larix laricina (DuRoi) Koch	+	*Thalictrum* sp.	R

* Ground cover values for *Sphagnum affine* and *S. palustre* are combined and listed under *S. affine* because it was not possible to separate these two taxa in the field.

than 1%). Ground cover values for *Sphagnum* and other bryophytes were also determined. Voucher specimens are deposited in the Herbarium of the New York State Museum, Albany, NY and in the Herbarium of Binghamton University, Binghamton, NY. Nomenclature follows Mitchell (1986) for vascular plants, Andrus (1980) for *Sphagnum,* and Anderson et al. (1991) for other mosses. The diameters of all trees having a d.b.h. $\geq$ 2.5 cm were measured in a 250 m^2 subplot. Tree height in the releve was determined with a Suunto clinometer. The age of two Atlantic white cedars was determined by tree cores (taken at 1.4 m above ground level). To avoid harming the living Atlantic white cedar, cores were taken from trees which had recently died. In addition, two standing dead Atlantic white cedar saplings were cut down and their age determined by counting annual growth rings at about 5 cm above the ground. Water samples were collected from the area of the releve in September and November 1995 and February and May 1996. A UniFET FieldLAB-100 pH meter was used to measure pH and specific conductivity (25°C) was measured with a Fisher Model 152 Conductivity Meter. A corrected specific conductivity (K_{corr}) was obtained by adjusting the conducitivity readings for H^+ concentrations (Sjors 1952). Concentrations of Ca^{++} (mg/l) were determined by the EDTA titrimetric method (LaMotte Model PHT-CM-OR).

Results. Table 1 lists the plants found in the 0.1 ha releve. Atlantic white cedar was the dominant tree (basal area = 42.1 m^2/ha; density = 1400 trees/ha; maximum d.b.h. = 39 cm, mean d.b.h. = 18 cm), with red maple (*Acer rubrum,* basal area = 12.8 m^2/ha; density = 920 trees/ha; maximum d.b.h. = 22.5 cm, mean d.b.h. = 12 cm) and larch (*Larix laricina,* basal area =

Table 2. Size class distribution of all trees ≥2.5 cm d.b.h. in a 250 m^2 subplot in the releve at the Pine Island Cedar Swamp.

Species		d.b.h. (cm) ≤10	10–15	15–20	20–30	30–40	Total
Chamaecyparis thyoides	live	1	11	10	11	2	35
	dead	20	4	1	1		26
Acer rubrum	live	9	8	2	4		23
	dead	2					2

0.5 m^2/ha; density = 10 trees/ha; d.b.h. = 26 cm [only one tree present in the releve]) being the only other trees present (Tables 1, 2). The tallest trees were 20–25 m tall. Live branches on the Atlantic white cedar were limited to the tree canopy, which started about 8–9 m above the ground. Total basal area for the releve was 55 m^2 ha, with over 75% of that being contributed by Atlantic white cedar. Outside of the releve, but within the Pine Island Cedar Swamp, there were two large Atlantic white cedar logs with 50 and 51 cm d.b.h., respectively, indicating that the site had once supported larger trees.

One of the dead trees which was cored had been an understory tree (77 years, 18.5 cm d.b.h., mean annual radial increment of 1.2 mm). The second had been a canopy tree (d.b.h. = 28.9 cm) and unfortunately had a partially rotten interior; only a 8.1 cm core was extracted from this tree (49 years, mean annual radial increment of 1.7 mm). Based upon the above two mean annual radial growth rates, a complete core from this tree would have shown an age of 85–102 years (plus the time it took to grow to 1.4 m) and the largest living Atlantic white cedar present (39 cm d.b.h.) would be 115–163 years old (plus the time it took to grow to 1.4 m). The two dead saplings had had slower growth rates (50 years, 11.4 cm diameter, mean annual radial increment of 1.1 mm; 60 years, 10.0 cm diameter, mean annual radial increment of 0.8 mm) than the two trees which were cored.

Vaccinium corymbosum was the dominant tall shrub and *Toxicodendron radicans* was the most prominent small shrub (Table 1). *Rhododendon viscosum, Lyonia ligustrina, Lindera benzoin, Toxicodendron vernix, Amelanchier canadensis, Ulmus americana,* and *Fraxinus nigra* were also present in the shrub layer, but each had < 1% ground cover. Although red maple seedlings were abundant (5–10% ground cover) in September 1995, especially in the unflooded depressions, most of these were killed when the depressions were refilled with water later in the fall (after the drought ended). Only a few Atlantic white cedar seedlings were observed and all of these occurred on the mounds, well above the normal high water level.

The ground surface was a mosaic of mounds (where the trees and shrubs occur) and depressions which are often filled with water (mound and pool microrelief [Golet et al. 1993]). Large depressions cover 25 to 50% of the ground surface, with mounds (reaching up to 45 cm above the basins of the depressions) making up the balance. The depressions are largely unvegetated and frequently have water in them. Although no standing water was present in mid-September 1995, during an unusually dry period, water (up to 20 cm deep) was present in the depressions when I visited the swamp in November 1995, February 1996 and May 1996. The upper 20 to 30 cm of the mounds was vegetated, with *Sphagnum* (mostly *S. fimbriatum, S. palustre, S. affine,* and *S. bartlettianum*) and *Coptis trifolia* being the dominant plants growing on their surface (Table 1). *Osmunda cinnamomea, Symplocarpus foetidus,* and *Thelypteris palustris* were also prominent, occurring both on the mounds and in the shallower portions of the depressions. *Aulacomnium palustre, Leucobryum glaucum,* and *Thuidium delicatulum* commonly occurred on the mounds and *Hypnum imponens* carpeted the small logs which were elevated above the water level. Liverworts (*Bazzania trilobata, Jamesoniella autumnalis,* and *Pallavicinia lyellii*) were a minor component of the ground layer. *Clintonia borealis* and *Sphagnum wulfianum* were the most noteworthy of the less common species present.

Although not present in the releve, *Rhododendron maximum* L., *Myrica gale* L., *Lycopodium lucidulum* Michx., *Tsuga canadensis* (L.) Carr. (only two trees) and several additional species of *Sphagnum* (*S. contortum* Russ., *S. henryense* Warnst., *S. quinquefarium* [Braithw.] Warnst., *S. russowii* Warnst., and *S. teres* [Schimp.] Angstr.) also occurred in the Pine Island Cedar Swamp or in its immediate vicinity. Larch, although limited to the periphery of the releve, was scattered throughout the rest of the Pine Island Cedar Swamp. Prominent species in the surrounding hardwood swamp include *A. rubrum, Ulmus americana, Betula alleghanensis* Britt., *Fraxinus nigra, Toxicodendron vernix, Ilex verticellata* L., *Lyonia ligustrina* (L.) DC., *Osmunda cinnamomea, Symplocarpus foetidus,* and *Impatiens capensis.*

Having a dolomite bedrock system, the Pine Island Cedar Swamp has a more minerotrophic environment than that typically associated Atlantic white cedar wetlands (Laderman 1989). It has a moderately to mildly acid (pH 4.7–5.9) and a moderately to strongly minerotrophic (10–40 mg/l Ca^{++}, K_{corr} = 50–200 μmhos/cm) water regime. Although the pH did not vary much over time, Ca^{++} concentrations and conductivity did vary significantly, with less mineralized conditions occurring after heavy rainfall and after periods of extensive snow melt.

THE DURLANDVILLE HARDWOOD SWAMP. Some 20 mature Atlantic white cedar (maximum d.b.h. = 43 cm) still persist scattered throughout the 25 ha hardwood swamp at Durlandville. Although no regeneration of Atlantic white cedar was observed in the forest interior, there were two small clearings along the perimeter of the hardwood swamp where Atlantic white cedar seedlings and saplings were present. One of these was about 0.2 ha in extent and had been cleared about 15 years ago. An extensive carpet of *Sphagnum* (*S. fimbriatum, S. henryense, S. palustre, S. recurvum,* and, a species not found at the Pine Island Cedar Swamp, *S. magellanicum* Brid.) covered the ground and a sward of Atlantic white cedar seedlings and saplings (up to 3 m tall, many having cones) occurred in the southern third of the clearing. In strong contrast, there were no Atlantic white cedar seedlings and saplings in the adjacent hardwood forest and *Sphagnum* had a very limited presence there. Although *Sphagnum* and Atlantic white cedar were quite prominent at the present time, other plant species typical of inland Atlantic white cedar peat swamps were notably absent. Water samples collected from this site in mid-November 1995 had a water chemistry (pH 4.5–4.7, 35–40 mg/l Ca^{++}, K_{corr} = 180–190 μmhos/cm) similar to the that of the Pine Island Cedar Swamp sampled in the same time period (pH 4.7–4.9, 27–40 mg/l Ca^{++}, K_{corr} = 155–200 μmhos/cm).

When this site was cleared, the uprooted trees had been placed in piles in the middle of the clearing. As many of these were Atlantic white cedar, this particular area may have been a small cedar swamp. Unfortunately, whatever the ecosystem might have been, it has been largely obliterated. Only one mature Atlantic white cedar (about 30 cm d.b.h.) had been left standing at this site (it died in late 1995), and it was undoubtedly the primary seed source for the current generation of saplings and seedlings. Although the clearing is subjected to moderate drainage, it has remained wet enough (water table ≤30 cm) to support a good growth of *Sphagnum* and this in turn has provided an excellent environment for the reproduction of Atlantic white cedar. If protected from further drainage and clearing, it would be a prime place to mount a cedar swamp restoration project.

Discussion. Although the Pine Island Cedar Swamp presently occupies about 1 ha, it was once far more extensive. Evidence of Atlantic white cedar (stumps, snags and logs) occurs throughout much of the adjacent hardwood swamp. A few mature Atlantic white cedar and larch still sporadically occur in the hardwood swamp as well. The presence of larch, which is a shade intolerant species, indicates that the original cedar swamp must have had some areas with a fairly open tree canopy. However, there is no evidence of recent successful reproduction by larch. The smallest larch observed had a 14 cm and most had a d.b.h. >20 cm (maximum d.b.h. = 40 cm).

The best preserved portion of the Pine Island Cedar Swamp (covering about 0.1 ha) is also the wettest part of the entire swamp complex. It is the only area where Atlantic white cedar is the dominant tree species and there is no evidence that it has ever been logged. As one moves away from the core area of the Pine Island Cedar Swamp, hardwoods become more dominant and Atlantic white cedar (as well as the other cedar swamp plant species) gradually drop out. Indeed, many of the plants associated with the cedar swamp do not occur, or have a very limited presence, in the hardwood swamp. Because of this, and also because of the presence of a well developed mound and pool microrelief, the Pine Island Cedar Swamp is quite distinct from the surrounding hardwood swamp.

The mean annual radial increments of the Atlantic white cedar are comparable to those found in other Atlantic white cedar swamps in the northeastern United States (Golet and Lowry 1987). The relatively robust growth rate of the one canopy layer tree which was measured (1.7

mm mean annual radial increment) indicates that lack of light, and not high water levels, is the major reason for the reduced growth rates of the subcanopy Atlantic white cedar (0.8 to 1.1 mm mean annual radial increment). The long period of suppressed growth evidenced by the subcanopy Atlantic white cedar further indicates that there has been a relatively dense tree canopy associated with the core area of the cedar swamp for at least the past 50 years.

The tree data indicate that the core of the cedar swamp is in a state of flux (Table 2). Although Atlantic white cedar was once well represented by individuals in all age groups in the releve, indicating that a more open tree canopy existed, and/or that the increased exposure to light that resulted from the logging of the surrounding cedar swamp had allowed for a brief period of successful establishment, regeneration is now minimal. Live Atlantic white cedar saplings <10 cm d.b.h. are notably absent. A large number of dead saplings do occur in the core area, some recently dead and others having been dead for quite some time. Most, if not all, of these were established more than 50 years ago. Only a few Atlantic white cedar seedlings were observed and none of them appeared to be more than a few years old. As Atlantic white cedar seedlings may survive for up to three years under a mature cedar canopy (Laderman 1989; Little and Garrett 1990), these seedlings simply represent short term establishment. White tail deer are present in the hardwood swamp, but there was no evidence that their browsing activities were significantly affecting Atlantic white cedar regeneration. In strong contrast to Atlantic white cedar, there were thousands of red maple seedlings in the releve, and this species was well represented in the sapling to young tree size classes (Table 2). Red maple, which has faster growth rates and is shade tolerant, can displace Atlantic white cedar if no perturbations prevent it from doing so (Carter 1987; Day 1987; Roman et al. 1987). Thus if current trends continue, red maple will become the dominant species and Atlantic white cedar and larch, both shade intolerant species, will decline and perhaps even be extirpated.

DISTURBANCE HISTORY OF THE PINE ISLAND CEDAR SWAMP. The two major perturbations which have affected the Pine Island Cedar Swamp are long term drainage and logging. Extensive drainage systems have been in place throughout the former Drowned Lands region for well over 150 years, and these have lowered the regional water table. An abandoned (and now peat filled) drainage ditch runs through the eastern edge of the Pine Island Cedar Swamp, providing graphic evidence of drainage activity. As the Pine Island Cedar Swamp occurs in the midst of a large wooded lot which has never been utilized for farming, the local water table associated with it has not drawn down as much as it has been in the surrounding, highly drained farm fields. However, the local water table was lowered enough to affect the sustainability of much of the former cedar swamp and this, combined with the extensive logging which occurred there, resulted in the development of a hardwood swamp in its place. Water levels high enough to maintain a cedar swamp environment only occurred in the lowest lying portion of the Pine Island Cedar Swamp, a small area which for some reason was also not logged.

In addition to drainage, Atlantic white cedar was intensively harvested from the Pine Island Cedar Swamp from the 1930s to the early 1950s. Well over a hundred (perhaps several hundred) Atlantic white cedar, averaging 30 cm d.b.h., were harvested each winter and used to make onion crates by Jess Van Sickle (Richard Van Sickle and Frances Sodrick, pers. comm.). The historian for Pine Island (Frances Sodrick) has a photograph of the saw mill which processed the harvested cedar logs, several of which are visible in the picture. One local farmer remembered that cedar having ≥60 cm d.b.h. had been taken from the Pine Island Cedar Swamp. In addition to taking live trees, even the large cedar logs, which are a common component of cedar swamps, appear to have been removed. Because they are resistant to decay and provide useful wood, it was a common practice in the Drowned Lands to harvest cedar logs as well as the living trees.

Although not itself logged, the small core area of the Pine Island Cedar Swamp would have been significantly affected by logging. What was once a protected interior portion of a cedar swamp became an "edge environment" after logging. Until the surrounding area became reforested, the core area of the Pine Island Cedar Swamp would have experienced increased temperatures, more exposure to light, lower humidity levels, and more air movement. Given its small size and the limited tolerance of many of its component species, this change in microclimate would have been quite significant.

Although anthropogenic nutrient enrichment has been found to significantly affect the species composition and structure of coastal Atlantic white cedar peatlands (Ehrenfeld 1983), it is not a major variable in the case of the Pine Island Cedar Swamp. Even though surrounded by an extensive agricultural region, water is drained from the swamp and the adjacent agricultural fields by well developed drainage systems (drainage ditches are up to 2 m deep). Thus the influx of nutrient enriched waters from agricultural fields into the cedar swamp is not likely. The absence of significant nutrient enrichment is one reason why the core of the Pine Island Cedar Swamp has remained relatively intact.

COMPARISON WITH OTHER INLAND ATLANTIC WHITE CEDAR PEAT SWAMPS. Only a handful of inland Atlantic white cedar peat swamps are now found in northern New Jersey and adjacent portions of New York (Karlin 1997). Although the Pine Island Cedar Swamp has much in common with these peatlands, it is also quite distinct from them. While it occurs at a low elevation (119 m above sea level) in the broad floodplain of the Wallkill River, all of the other extant inland Atlantic white cedar peat swamps in this region occur in isolated upland areas (elevations ranging from 216 to 454 m above sea level) which include the highest elevation of occurrence for Atlantic white cedar (Laderman 1989). Most are associated with strongly acid (pH 3.5–4.7) and weakly to moderately minerotrophic (<5 mg/l Ca^{++}; K_{corr} $\leq$40 μmhos/cm) water regimes. Only one other inland Atlantic white cedar peatland in this region (McAfee Swamp) is associated with a moderately to mildly acid (pH 4.6–6.1) and moderately to strongly minerotrophic (5 to 30 mg/l Ca^{++}; K_{corr} 40–210 μmhos/cm) water regime (Karlin 1997). The water chemistry is variable at the latter site (as it also is at the Pine Island Cedar Swamp), with moderately minerotrophic conditions occurring right after heavy rains and during periods of extensive snow melt and strongly minerotrophic conditions being present at other times. Although the ranges overlap, the maximum Ca^{++} concentrations at McAfee Swamp are lower than those at the Pine Island Cedar Swamp.

Several of the plant species present at the Pine Island Cedar Swamp, notably three *Sphagnum* species (*S. contortum, S. teres, S. wulfianum*) and *Ulmus americana,* are not found at any of the other inland Atlantic white cedar peat swamps in this region, including McAfee Swamp. Indeed, there does not appear to be any previous report of the three *Sphagnum* species associated with Atlantic white cedar in any other region. All four species are usually associated with moderately to strongly minerotrophic environments and, with the exception of *Sphagnum wulfianum,* all occur in the fens and rich fens of northern New Jersey (Karlin and Andrus 1988; Karlin 1997). Although clearly belonging to the acid peatland complex of Karlin (1997), the vegetation of the Pine Island Cedar Swamp represents a unique transitional position between the acid peatland complex and the rich fen complex.

In addition, there are several species which are typically found in inland Atlantic white cedar peat swamps which are not present at the Pine Island Cedar Swamp. These include *Calla palustris* L., *Carex trisperma* Dewey, *Drosera rotundifolia* L., *Nyssa sylvatica* Marsh., *Picea mariana* [Mill.] BSP., and *Sarracenia purpurea* L. (Niering 1953; Montgomery and Fairbrothers 1963; Belling 1977; Lynn 1984; Karlin 1997). These species probably did occur in the extensive cedar swamps which once covered much of the Drowned Lands, but all appear to have been extirpated. For instance, one local natural historian (Jack Webster, pers. comm.) believes that *Picea* (*P. mariana* and/or *P. rubens*) was once found in the Drowned Lands cedar swamps. The absence of these species from the Pine Island Cedar Swamp is most probably due to the extensive perturbation that the swamp has experienced, its small size, and its isolation from other similar peatlands. Ehrenfeld (1983) found that 25% of the plant species occurring in pristine swamps in the New Jersey Pine Barrens were not found in swamps in developed areas which had been subjected to changes in hydrology and water chemistry.

The minimal presence of liverworts is also noteworthy. They are a prominent component of the inland Atlantic white cedar swamps in northern New Jersey and adjacent New York (Reschke 1990; Karlin 1997). Their lack of abundance can be explained in part by the lack of large old logs (most of which were removed when the cedar swamp was logged). The prime liverwort habitat in Atlantic white cedar swamps is on large, old logs which are partially immersed in the peat. There were several small logs in the cedar swamp, but most were elevated well above the ground surface and largely covered by *Hypnum imponens,* not by liverworts. The change in microclimate associated with logging (see above) is another significant variable, with liverwort populations declining or being extirpated because of the increased exposure to light, wind, and lower humidity levels.

Conclusion. The present day vegetation of the Pine Island Cedar Swamp does not fully represent what the vegetation of the Drowned Lands cedar swamps once was. It is only one small, isolated site and its species composition and ecological relationships have been significantly altered by human activities. As noted above, several species which commonly occur in inland Atlantic white cedar swamps have probably been extirpated. In addition, several species which are not usually associated with pristine inland Atlantic white cedar peat swamps (*Lindera benzoin, Impatiens capensis, Onoclea sensibilis, Parthenocissus quinquefolia, Ulmus americana*) occur there. Although this latter group of species is still not common in the core area of the Pine Island Cedar Swamp (where the releve was located), they are prominent components of the surrounding hardwood swamp and those portions of the Pine Island Cedar Swamp which grade into the hardwood swamp.

In spite of the changes noted above, the inner core of the Pine Island Cedar Swamp remains remarkably intact. Atlantic white cedar remains dominant, the mound and pool microrelief is well developed, and several plant species typical of inland Atlantic white cedar peat swamps still occur there. Among the more noteworthy remnants would be the *Sphagnum* flora, which is relatively diverse (12 species), especially considering the perturbations that have taken place. This is somewhat surprising, because *Sphagnum* species are often quite sensitive to changing environments. The fact that anthropogenic nutrient enrichment has been minimal at this site is probably a major reason why the *Sphagnum* flora has been so well maintained. *Sphagnum contortum, S. quinquefarium,* and *S. wulfianum* are new records for Orange County and the site represents their southernmost occurrence in New York (Andrus 1980). It is also the lowest elevation (about 119 m) that *S. wulfianum* is known from in the southern part of its range. In addition, the presence of *S. contortum, S. teres,* and *S. wulfianum* is unique for Atlantic white cedar peat swamps. The richness of the present *Sphagnum* flora, which is probably just a small remnant, and the presence of one additional species (*S. magellanicum*) at the Durlandville site suggests that the Drowned Lands once had a robust and diverse assemblage of *Sphagnum*.

Although the Pine Island Cedar Swamp has persisted until the present, the environmental regime which has allowed for its preservation has not remained static. Unfortunately, the changes that have occurred do not enhance its sustainability. The hardwood swamp which replaced the logged portions of the cedar swamp is maturing and creating an environment increasingly unsuitable for the regeneration of Atlantic white cedar, larch and most of the other plant species associated with the cedar swamp. Thus the area where these species can survive is becoming more limited with time. Secondly, a 25 ha portion of the hardwood swamp was cleared and converted to agricultural land within the past 25 years and there is a chance that even more will be lost in the near future (80 ha have been converted to agricultural land at the Durlandville site in the same time period). This progressive loss of the surrounding hardwood swamp means a decreasing buffer for the Pine Island Cedar Swamp, especially in terms of maintaining a locally elevated water table. Finally, a more efficient drainage system has been installed in adjacent agricultural fields within the past 10 years (Steve Urbanski, pers. comm.), and this most likely has had an impact on the water table of the Pine Island Cedar Swamp.

As has already been amply demonstrated in the former areas of the Pine Island Cedar Swamp now occupied by hardwood swamp, and, indeed, at all of the sites where extensive cedar swamps once existed in the Drowned Lands, the majority of species associated with the Pine Island Cedar Swamp will be extirpated if the ecosystem which provides the environment essential for their survival declines and ultimately disappears. However, simply protecting the Pine Island Cedar Swamp from development at this point of time may not be sufficient to ensure its continued existence; some additional level of management may also be required. If nothing is done, then the sole remnant of the once extensive Drowned Lands cedar swamps is truly making its last stand.

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