Fiddler's Green Bog:
A Report on the Current Status and Recommendations for Future Direction

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Abstract

Conservation of wetland areas is a priority for land conservation organizations. Fiddler's Green contains unique wetland areas, most notably a bog, which is one of few remaining in central New York. The goals of this report are to map the property, define the bog perimeter, provide data that will indicate the current health status of the bog, and provide future direction and recommendations for ongoing management of the bog in Fiddler's Green. The open area analysis indicates that the open bog has shrunk considerably over time. The pH tests, however, indicate that the bog ecosystem is in good health, and that the encroachment of pioneer species has not significantly changed the physical conditions characteristic of bogs. Despite the decline in open area, the bog habitat can be maintained through active management and ongoing supervision.

Introduction

Fiddler's Green is a 78-acre property in Madison County, New York in the town of Eaton. The property is located off route 26, south of Leland Pond, and the northern edge of the property extends to Pecks Road. The property contains important ecological features including a bog, which is the main focus of this report. The bog is located in the northeast corner of the property, and contains two distinct pieces of open, unforested area; a larger section further north, about 40m in diameter, and a smaller open piece located, more or less, directly to the south.

The Nature Conservancy currently owns the property; however, Southern Madison Heritage Trust (SMHT) has taken a role in stewardship of the area. SMHT works to protect natural resources through the conservation of land, water, unique habitats, scenic landscapes, recreational sites and historic features through responsible land management, public education, and support of practices that advance natural resource conservation. The organization is interested in protecting Fiddler's Green from development, specifically the bog, because it is a unique and ecologically important and valuable ecosystem.

This report provides background information on the property, as well as data on the current state of the bog that can be used as preliminary information for SMHT's ongoing effort to conserve and protect the area. Colgate University may also integrate the property into their Environmental Studies program. In addition to mapping the property and defining the bog perimeter, this report also provides recommendations for removal of bog pioneer species, so that the area can continue to exist as a wetland, providing a unique habitat for plants and animals, as well as providing ecosystem services to the public.

Fiddler's Green Property

The Nature Conservancy acquired the area now known as Fiddler's Green in several pieces over a period of about 30 years. The manner of acquisition explains the irregular configuration of the property as a whole. Parcels 1-7, 1-8, and 1-9 (Figure 1) were the first parcels obtained by the Nature Conservancy, and were acquired in 1968 via a donation from Frank and Dorothy Selinsky. The donors had those properties surveyed and defined in the 40's and 50's, before eventually giving them as a package to The Nature Conservancy. Parcel 1-9 contains the bog, so the acquisition of this feature probably triggered the Nature Conservancy to pursue the surrounding parcels to protect the wetland.

Parcels 1-14, 1-16, and 1-17 (Figure 1) were acquired in 1984, 1983, and 1988, respectively. However, unlike the original properties they were not given as a donation by a private landholder. At a certain point in time tax payments on these parcels of land ceased to be paid. After a period of this inactivity the county treasurer, Harold C. Landers, took over ownership of the land, buying it on behalf of the county. The treasurer was then allowed to sign over the parcels to a third party (The Nature Conservancy) for Madison County. Each of these three parcels was procured individually in this manner.

Parcel 1-15 (Figure 1) was the final property received by the Nature Conservancy. The organization acquired this piece from the Snitchler family in 1997, giving Fiddler's Green its current shape and size. The property deeds and tax maps for these properties are attached to this report, and are available at the Madison County Clerks Office.

Surrounding Area

Several surrounding properties contain forested area. Parcel 1-18 contains 6.67 acres of vacant, in tact woodland. Parcel 1-12 contains 20.69 total acres, 10 of which are tillable and currently used for agricultural purposes. The property also contains 10.69 acres of woodland. Parcel 1-13 contains 1.89 acres of vacant swamp, and parcel 1-3.21 contains 24.85 acres of woodland.

Bog Ecology

Bogs are defined as freshwater wetlands that receive more precipitation from rainfall than they lose through evapotranspiration (Mitsch & Gosselink, 2000). *Sphagnum* bogs develop due to abundant *Sphagnum* growth over prolonged periods of time in undrained or poorly drained, glacial depressions (Rigg, 1919). *Sphagnum* is the most important bog forming plant because it develops quickly in very wet habitats (Potzger, 1934). *Sphagnum* moss creates a sponge-like mat due to the intertwining of its shoots, and can hold vast amounts of water (Potzger, 1934). This growth leads to the development of the floating mat that is so characteristic of bogs; the moss covers the water surface, then begins to grow up on top of itself, drawing the water up through the original *Sphagnum* growth creating a zone of saturation (Nichols, 1915). Additionally, *Sphagnum* creates unique environmental conditions that other plants and organisms must deal with (Rigg, 1940). The moss, in part, contributes to the acidic conditions typically found in bogs (Clymo et al., 1984; Rigg, 1940). The pH of a specific bog can vary; values ranging from 3.3-4 are normal (Clymo, 1984), but can be as high as 5 (Rigg, 1940). *Sphagnum* creates a highly specialized environment, in which only a small set of plants can thrive. Thus, *Sphagnum* bogs are very unique ecosystems that require conservation and management efforts.

Generally, bogs display typical patterns of zonation starting from the center of the bog and moving out into the more forested area. The bog itself will be comprised of the *Sphagnum* mat, along with typical bog plants that can tolerate the conditions created by *Sphagnum* moss, such as pitcher plants, sundew, and bog laurel. Outside of the bog, however, are bands of woody vegetation. Low shrubs grow nearest the water's edge. Small, young conifers and low shrubs grow in the next zone. Even further from the edge of the bog taller shrubs and trees grow, and finally a mature conifer forest typically surrounds the bog (Nichols, 1915). Additionally, bogs are often separated from the forest around them by a ditch that can be filled with water during the wetter times of the year (Nichols, 1915).

Bogs, like other wetlands, are constantly changing; overtime the habitat type can shift from bog to forest and back again. This shift in habitat type is referred to as succession. Decreases in *Sphagnum* cover are often correlated to an increase in shrub and tree cover (Gunnarsson et al., 2002; Malmer & Wallén, 2004). Additionally, increased rates of tree growth in bogs correlate to vanishing *Sphagnum* cover (Lewis & Dowding, 1926). These changes in vegetation and forest cover create an interesting dynamic between bogs and the surrounding forest.

At times, the climatic conditions may promote the invasion of forest into a given bog. Previous studies have shown that drier environmental conditions allow for an increase of woody vegetation in bog ecosystems (Bridge et al., 1990). Furthermore, drier environmental conditions tend to promote the advancement and colonization of woody vegetation, both shrubs and trees, into bog habitats (Booth & Jackson, 2003; Kuhry, 1997). This invasion of open bogs by woody shrubs and trees is a natural process that can be driven by changes in long-term climatic conditions (Malmer & Wallén, 2004; Gunnarsson et al., 2002; Pellerin & Lavoie, 2003).

Drainage, or lowering of the water table, also affects the type of vegetation that occupies bog habitats. Drainage can be a natural process, and therefore should not be thought of as only an anthropogenic force. In this paper, drainage is used to mean drying out and lowering of the water table through natural succession. Studies have shown that drainage promotes the surrounding tree species to invade bogs (Laine et al., 1995; Minkkinen et al., 1999). Furthermore, Silvola et al. (1996) suggest that drainage is the key factor that starts the actual process of bog forestation.

Undoubtedly, drier environmental conditions and drainage affect the vegetation found in bogs, and it is possible that these factors work together to drive bog succession. Gunnarsson et al. (2002) conducted a study in Sweden in which the authors examined an open bog being invaded by shrubs and trees, while simultaneously losing *Sphagnum* cover. They attributed these changes to both drier climatic conditions and increased drainage of the bog. Pellerin & Lavoie (2003) conducted a similar study in Quebec and came to the same conclusions. Other experiments have also suggested that drainage coupled with drying climatic conditions are the main drivers of bog succession, leading to increased establishment of woody vegetation (Frankl & Schmeidl, 2000; Linderholm & Leine, 2004).

The physical conditions that affect and cause bog succession can, in fact, be influenced themselves by different types of vegetation within the bog. For example, drainage of a bog can drive the vegetation composition within the bog, promoting tree invasion and increasing tree cover in the open area of a bog, altering the bog habitat into more of a forest ecosystem (Talbot et al., 2010). These newly established trees can, in turn, accelerate the forestation process. Woody species draw out the moisture from the bog because that vegetation type increases net evapotranspiration of the system (Eppinga, 2008). This change in vegetation type means that the bog soil moisture decreases and the water table gets drawn down. This drying out allows for additional tree colonization, which further drains the bog, turning the bog into a forest (Eppinga et al., 2008; Talbot et al., 2010). Drainage and tree cover work in a positive feedback loop, driving the habitat toward a forested area. Clearly, drainage can have a big impact on bog succession and can affect the state of the bog-forest dynamic.

The pioneer species that are the first species to invade a bog during succession to the forest stage are commonly species contained in the conifer forests that surround bogs (Rigg, 1919). Pines are a common pioneer group (Rigg, 1917). Specifically, white pines have the ability to colonize bog habitats and explode in population over a short time period. Edens & Ash (1969) found that the invasion of a single white pine individual led to a stand of 339 trees in just over 70 years. Tamaracks, or larches, are another common pioneer conifer (Rigg, 1940).

A forested state is often considered to be the climax stage in bog succession (Rigg, 1940). However, natural succession toward a forested state is generally a considerably slow process because *Sphagnum* bogs are considered a very stable ecosystem over time (Pellerin & Lavoie, 2003). They can remain seemingly unchanged because of the conditions created by extensive *Sphagnum* cover. *Sphagnum* can grow over the shoots of other plants, displacing them (Nichols, 1915). Additionally, extensive *Sphagnum* colonization can prevent tree establishment, and can kill growing trees that have colonized the bog if it surrounds them (Rigg, 1919). In this way, *Sphagnum* bogs can hold back the forest, under natural processes, prolonging succession. Furthermore, the forestation process can naturally reverse itself, enlarging the open area of the bog (Rigg, 1917). Whether the bog grows or shrinks ultimately depends on the climatic conditions and health of the bog.

Bog Maintenance, Repair, and Restoration

Succession by native woody plants is a major problem for open bog maintenance (Nichols, 2004). If an open bog is the desired habitat type, then pioneer species that invade the open area must be managed. Several techniques can be used to accomplish removal of woody plant species (Managing Wetland Vegetation). The first technique involves physical cutting of the desired species. The means of accomplishing this task range from a few people using hand tools to a team of people using larger machinery. Girdling is another manual technique used to kill woody pioneer species in wetlands (Managing Wetland Vegetation). This management technique involves removing the bark at the base of the tree, cutting off nutrients to the roots, which kills the tree while leaving it standing. This technique can be used to reduce canopy cover, limiting shading.

There are several important considerations when it comes to mechanical management techniques. Physical removal of trees creates more open area, which can be aggressively colonized by other pioneer species (Managing Wetland Vegetation), so the area must be continuously monitored. Additionally, if trees are clipped or removed completely the debris should be removed from the area. The number of people working in the bog should also be kept as low as possible to minimize disturbance to the ecosystem.

Another documented technique for wetland vegetation management involves grazing. Livestock grazing can be controlled and used to control certain woody species, abating their invasion (Managing Wetland Vegetation). However, this is not a realistic option for the Fiddler's Green bog. The area is too isolated and not large enough to support livestock. Additionally, livestock would cause major disturbances in the bog, destroying, and possibly feeding on, the rare species located there. Applying this strategy in the case of Fiddler's Green is unrealistic, so grazing should not be considered.

Chemical control, or the use of pesticides, is a further technique that can be used to manage vegetation (Managing Wetland Vegetation). Pesticides can be applied as a spray or injected into specific targets. Injections are a more accurate, but less rapid form of application. Although pesticides can be effectively used in bog maintenance, chemicals should be used with caution in wetlands (Managing Wetland Vegetation). Chemical contaminates can cause problems in all ecosystems, and fragile wetland environments are particularly vulnerable (Donald et al., 1998). Approved pesticides must be used if this technique is pursued.

A final tool that can be used is fire (Managing Wetland Vegetation). Fires are considered a natural disturbance for some wetland areas, and therefore, can be used as a management technique. Controlled ground fires can be utilized to hold back invading vegetation. Torches can also be used to target specific individuals. Burning works most effectively when done in the winter or early spring (Managing Wetland Vegetation). In the past, the Nature conservancy has developed burn plans for other bogs under their jurisdiction (The Nature Conservancy: MD/DC chapter); this tool could also be used in the case of Fiddler's Green.

The hydrology of any wetland is an important quality. Bogs are poorly drained wetlands, giving them a unique hydrology. Altered water flow poses a threat to the longevity of a given bog ecosystem because drainage encourages further forestation of the open area (Talbot et al., 2010; Silvola et al., 1996; Pellerin & Lavoie, 2003). Therefore, the movement of water and water table location of any bog of interest should be one of the qualities monitored to establish its health (Roos, 1996; Miletti et al., 2005).

Raising the water table has been shown to be an effective means of bog management and repair (Farrick & Price, 2009). Wheeler and Shaw (1995) identified possible techniques for improving bog hydrology. Altering the water table can be difficult, as well as dangerous to the ecosystem if done improperly. Nevertheless, this strategy for bog restoration cannot be ignored as an extreme measure.

There are documented cases of bog restoration via *Sphagnum* replanting. Ferland & Rochefort (1997), Graf & Rochefort (2008), and Farrick & Price (2009) all comment on the success of reintroducing *Sphagnum* moss to degraded peatland areas. These studies indicate that *Sphagnum* can be taken from nearby bogs and used to reestablish *Sphagnum* cover in a struggling bog. All of these studies deal with peatlands that have been degraded due to economic harvesting of peat. Nevertheless, it is not unreasonable to think that *Sphagnum* could be replanted to help a bog abate the succession of the surrounding forest. Miletti et al. (2005), for example, recommended the planting of *Sphagnum* mats in a bog that had become extensively forested as a possible restoration technique.

Appropriate management strategies should be employed depending on the state and nature of the given bog. Furthermore, a combination of strategies may be the best approach in some cases. Whatever management or restoration techniques are chosen, it is clear that ongoing practices and maintenance efforts are required to prevent excessive succession and maintain open bog areas.

Fiddler's Green Bog

Little documentation exists on the specifics of Fiddler's Green and the bog. In 1972 Nancy M. Carroll described the bog in Fiddler's Green as a "quaking bog." This description means that the bog contained a floating mat layer with certain aquatic plants over the lake or pond on which it developed (Nichols, 1915). The bog is currently comprised of a floating *Sphagnum* mat, which contains bog plants, including leatherleaf and bog laurel. The area in and around the bog contains the following rare plant species: slender arrowgrass, grass pink, snake mouth orchid, pink shinleaf, bog twayblade, hooded ladies' tresses, ladies' tresses, southern twayblade, white fringed orchid, pod grass, and greater whorled pogonia. The bog also provides a habitat for reptiles and amphibians, including Four-toed, Jefferson's, and Spotted Salamanders.

Saulsgiver (1976) conducted a pollen analysis of the bog to track changes in vegetative conditions of the bog and correlate them to changes in environmental conditions of central New York. He found that the area had gone through several successive climatic changes since the start of the formation of the bog, which occurred during the Pleistocene glaciation: cool, moist; warm, dry; warm and moist; warm, dry; and cool, moist. These different environmental conditions favor the growth of different vegetation. Therefore, over this period of time, species composition and abundance in and around the bog changed, and the actual size of the bog itself may have fluctuated due to the altering environmental conditions. *Sphagnum* growth would have been encouraged during the cool, moist periods (Saulsgiver, 1976; Rigg, 1940), but growth could have been abated or even reversed during periods of other environmental conditions.

The aerial photo progression shows the current size of the bog compared to that in the past (Figures 2a-2f). The bog appears to have undergone considerable shrinkage since 1936. Additionally, two Colgate University professors commented on succession toward the center of the bog, noting that succession appeared to be greater within the last 20 years (from the time of their observations) (Saulsgiver, 1976; Goodwin). Carroll (1972) observed other signs of change in Fiddler's Green. The author noted that a considerable number of the birds had disappeared by 1972, which is significant considering at one point Fiddler's Green was said to have contain every species of bird found in Madison County (Caroll, 1972).

One previous case study (Miletti et al., 2005) offers a comparable situation to that observed at Fiddler's Green. The authors observed a bog in Ohio that had undergone severe succession towards forestation. They monitored several characteristics of the bog, including pH and nutrient levels, in order to determine its current health status. They concluded that the area of study was not, in fact, functioning as a true bog. The pH was as high as 7.41 in some areas and, in general, nutrient levels were higher than normal for a bog.

The situation observed in Ohio can offer insight into the bog at Fiddler's Green. Miletti et al. (2005) concluded that restoration of the bog in Ohio was probably not feasible due to the successional stage, as well as the natural conditions, which had altered drastically from normal bog conditions. The successional stage and the physical conditions indicated that the area was no longer a true bog. If the bog at Fiddler's Green continues to go unmonitored and unmanaged it will likely end up in a condition similar to that of the bog in Ohio. The open area would disappear, the hydrology of the bog would be lost, and the pH and nutrient levels would rise, eliminating bog conditions and rare species. Therefore, steps must be taken to ensure the maintenance of true bog conditions and species at Fiddler's Green.

Fiddler's Green Conditions

Methods

To determine the current condition of the bog in Fiddler's Green several measurement and monitoring approaches were employed. The bog's open area and perimeter of that area were digitized and estimated on ArcGIS using photographs from 1936, 1955, 1975, 2003, and 2008. The 2010 perimeter and open area were estimated on ArcGIS using GPS coordinates taken during a walk around the open bog perimeter in July 2010.

Soil pH was measured by conducting four pH transects that started in the open bog and extended well into the forested area (Figure 3). All transects began at the center of the northernmost open piece of the bog. Three soil samples were taken every 10 meters for 50 meters to a depth of 15cm. GPS coordinates were also taken at these points and mapped on ArcGIS (Figure 3).

The samples were allowed to air dry for one day before the pH of the soil was measured. The soil (2g) was suspended in 20mL of distilled water. The solution was mixed for 30 minutes then allowed to stand for one hour before the pH of the superficial liquid was taken.

A tree count and characterization was also done to determine the composition of pioneer species and areas that should be targeted for tree management. For each individual, the tree was identified, placed into a group (grove), and the diameter at breast height (DBH) was taken. The GPS coordinates of these groves were taken and mapped on ArcGIS (Figure 4). The identification was only carried out in the northern section of the bog.

Results

Open Area Decline

The amount of open area in the Fiddler's Green Bog has shrunk since the earliest photographic records (Figure 5). The total open area of the bog (estimated) has decreased from 4563 m^2 in 1936 to its current size of 727 m^2 (Figure 6).

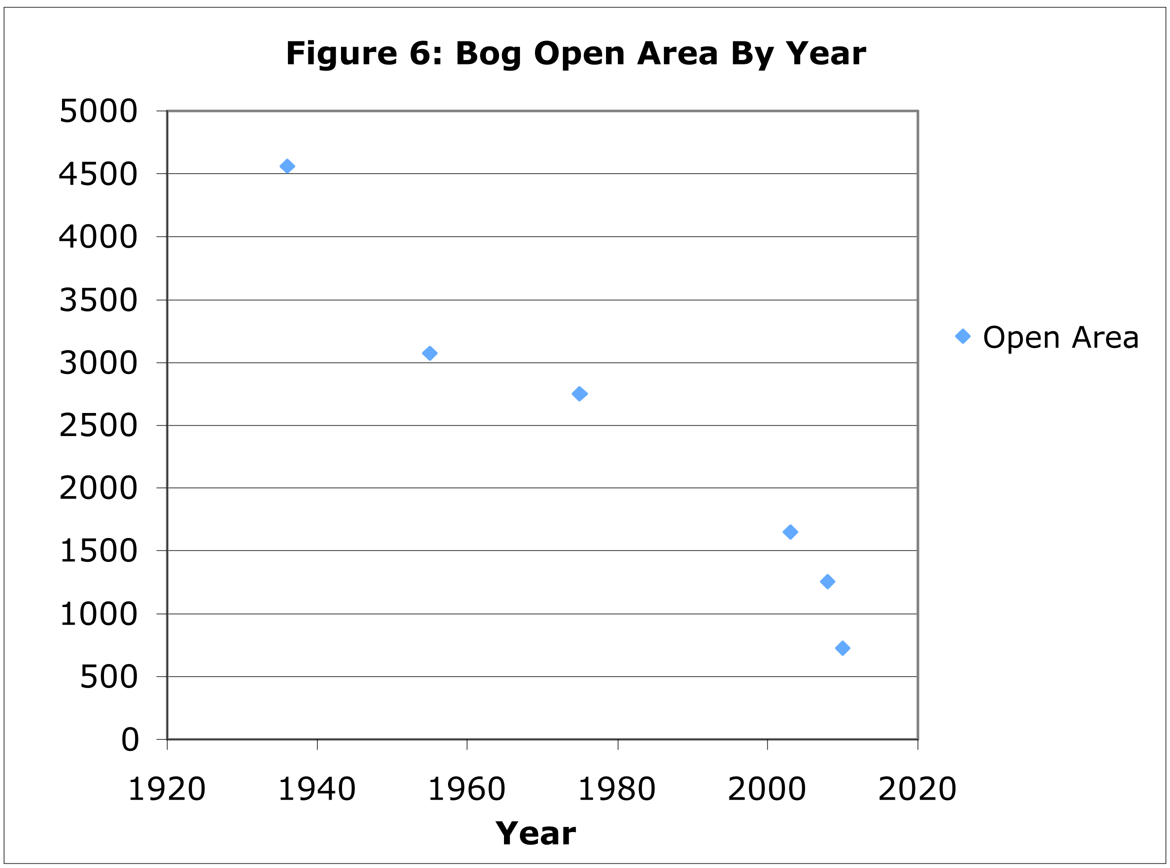

Figure 6 shows the amount of open area, i.e. unforested area, in the bog by year. The area values were obtained on ArcGIS using aerial photos from 1936, 1955, 1975, 2004, and 2008, and GPS coordinates taken in 2010. The open area has declined over this period of time from 4563 m^2 to 727 m^2.

pH Data

The pH average of all soil samples taken from the bog was 4.2, while the overall standard deviation was 0.24 (Figure 7). The lowest pH recorded was 3.8, while the highest was 4.5 (Figure 7).

Figure 7: Overview of pH Data	
Overall Average	4.206349206
Overall Standard Deviation	0.244865345
Low pH	3.8
High pH	4.6

Figure 7 shows a summary of the pH data gathered. The average pH of all soil samples throughout the bog was 4.2. The low pH value was 3.8, which was the only value under 4. No sample yielded a pH value higher than 4.6.

No transect had noticeably higher pH values than any other transect (Figure 8), and all soil samples yielded acidic ph values (Figure 7; Figure 8). Additionally, no transect had significantly higher pH values at the end of the transect than at the center (Figure 8).

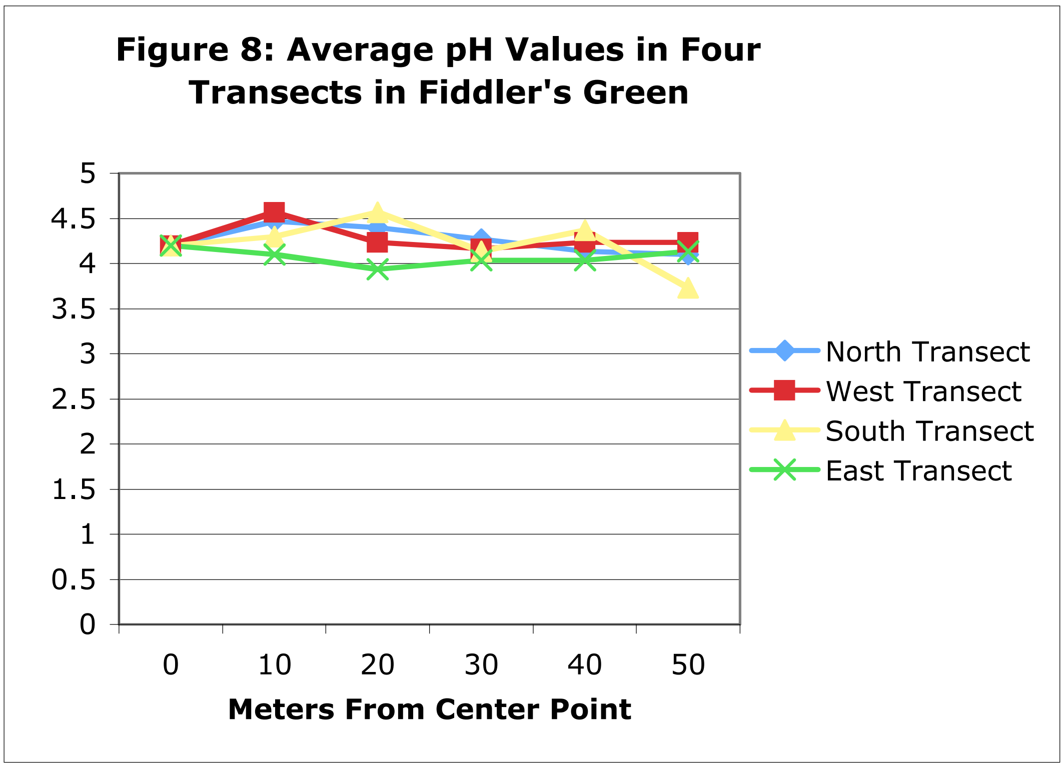

Figure 8 shows the average pH values at every distance away from the center for all four transects. Three samples were taken at the center of the bog, and then every 10 meters for 50 meters into the forested area in four directions. The average pH at every distance is represented on the graph. No direction displayed noticeably higher pH values than any other direction, and no transect showed an upward trend in soil pH as samples were taken into the forested area.

Pioneer Species Categorization

White pines and eastern tamaracks were the most common pioneer tree species identified (Figure 9). There were however, other tree species found in the groves of pioneer species (Figure 9). Additionally, the pioneer species identified here only include tree species; no shrubs were identified in this study.

Figure 9: Pioneer Species Composition		
Total Pioneer Individuals	153	Code
Total WP	98	WP=White Pine
Total ET	45	ET= Eastern Tamarack
Total RM	7	RM=Red Maple
Total YB	2	YB=Yellow Birch
Total H	1	H=Hemlock

Figure 9 shows the composition of pioneer tree species in the selected groves. A total of 153 trees were identified. 98 (64%) were white pine and 45 (29%) were eastern tamarack. Only 10 individuals of a total of 153 were not white pine or eastern tamarack. Only trees in the northern open piece of the bog were identified.

Figure 10 shows the total number of trees and average tree DBH in each grove identified. The areas encompassing groves 1-6 and 16-22 were the most highly populated regions. These groves had a high number of trees, but the average DBH per grove was relatively low (Figure 10) meaning that there were a greater number of smaller trees. This combination indicates a more dense area.

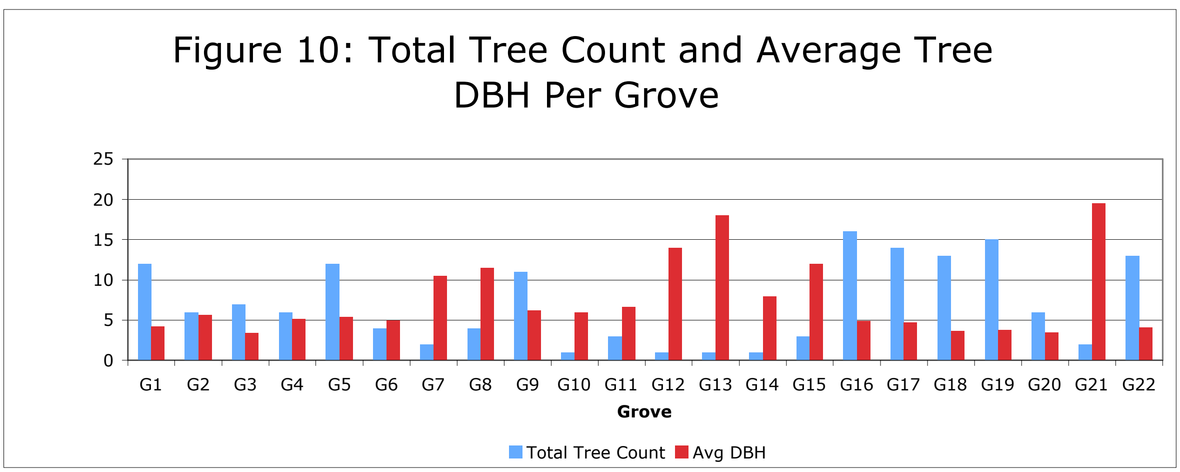

Figure 10 shows the total tree count for each identified grove, as well as the average DBH (cm) for trees in the specific groves. A high tree count with a low average DBH means there were many small trees in a given grove, while a low tree count with a higher average DBH indicates a grove with a few large trees.

Discussion

Open Area Decline - Fiddler's Green Projections

Several different projections, which model the decrease in open area, can be made for the bog at Fiddler's Green. With all the data points included in the graph, the decrease in open area can be modeled as a linear function by the line $y = -44x + 4300$ (Figure 11a). This model depicts the open area disappearing at a rate of $44m^2$ per year. If the area in 2010 is removed from the data set, the decrease in open area under natural succession can be represented by the line y = -41x + 4300 (Figure 11b), putting the rate of open area decline at $41m^2$ per year. With the first point (area in 1936) excluded, the trend line can be modeled by the curve $y = -0.81x^2 + 37x + 2600$ (Figure 11c). This model shows the open area disappearing at an accelerating rate as time progresses. In all projections y is the amount of open area (m^2) and x is the time elapsed (years) since the first picture taken of Fiddler's Green (1936).

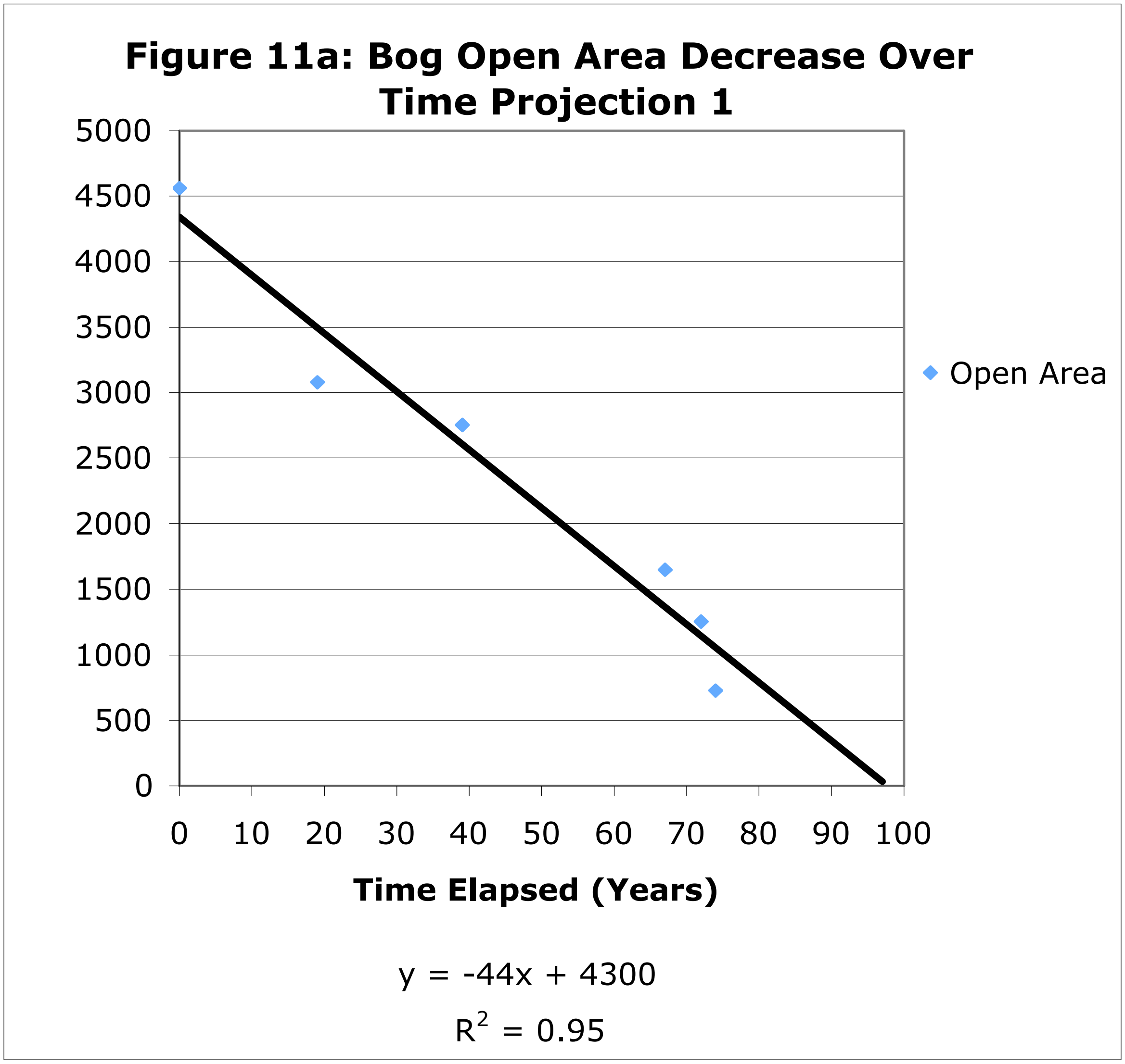

Figure 11a shows the decline of open bog area when the area from every year documented is included in the data set. Using these data, the projection for the decline of open area can be represented by the line y=-44x + 4300. The rate of decline of open area in this model is $44m^2$. *At this rate, the open bog will disappear in 2033.*

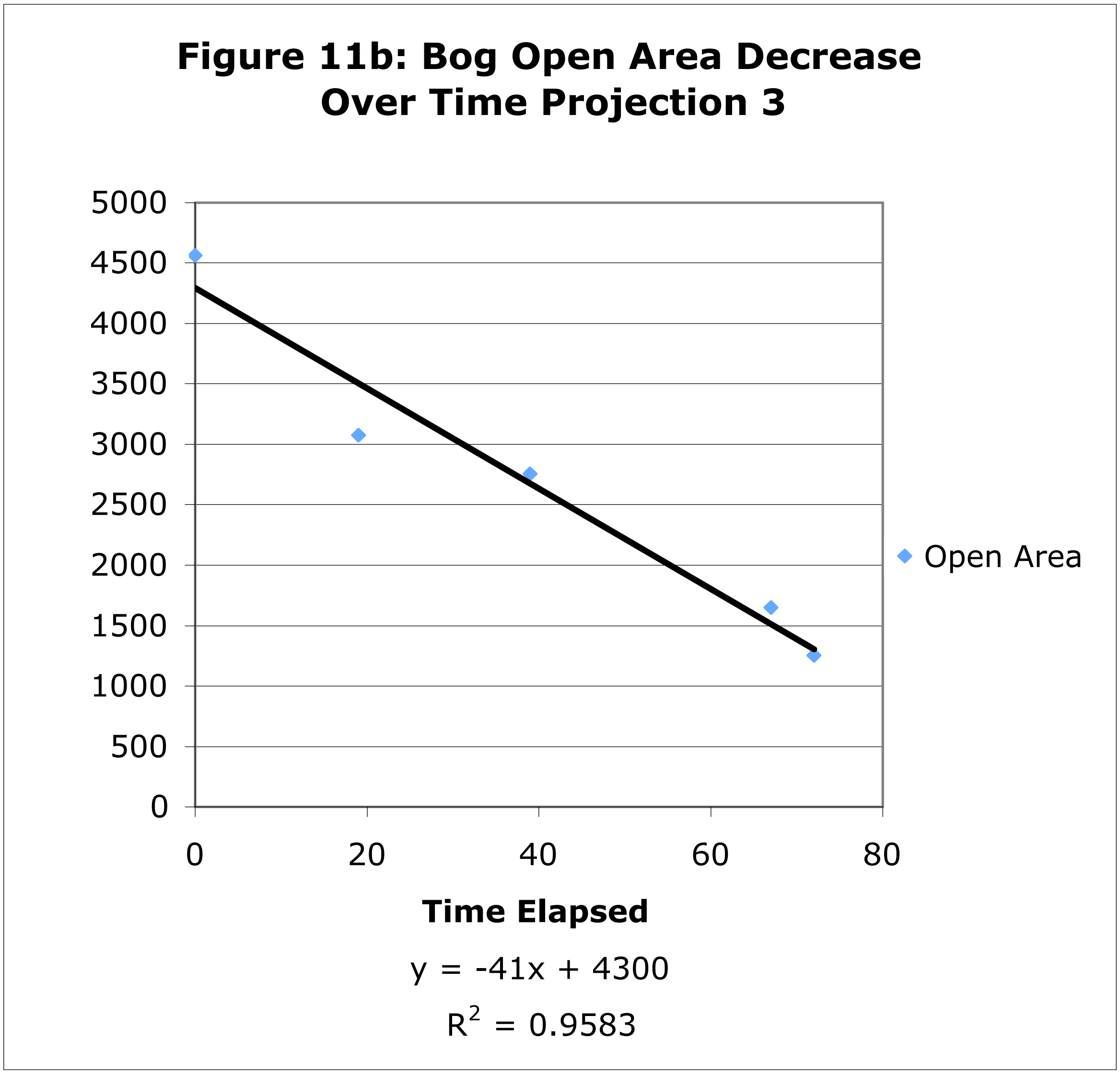

Figure 11b shows the decline of open bog area as a function of time. In this projection the estimated area from the year 2010 is excluded. The projection can be modeled by the equation y= -41x + 4300. In this model the open area is declining at a rate of 41m² per year, and will vanish completely in 2040.

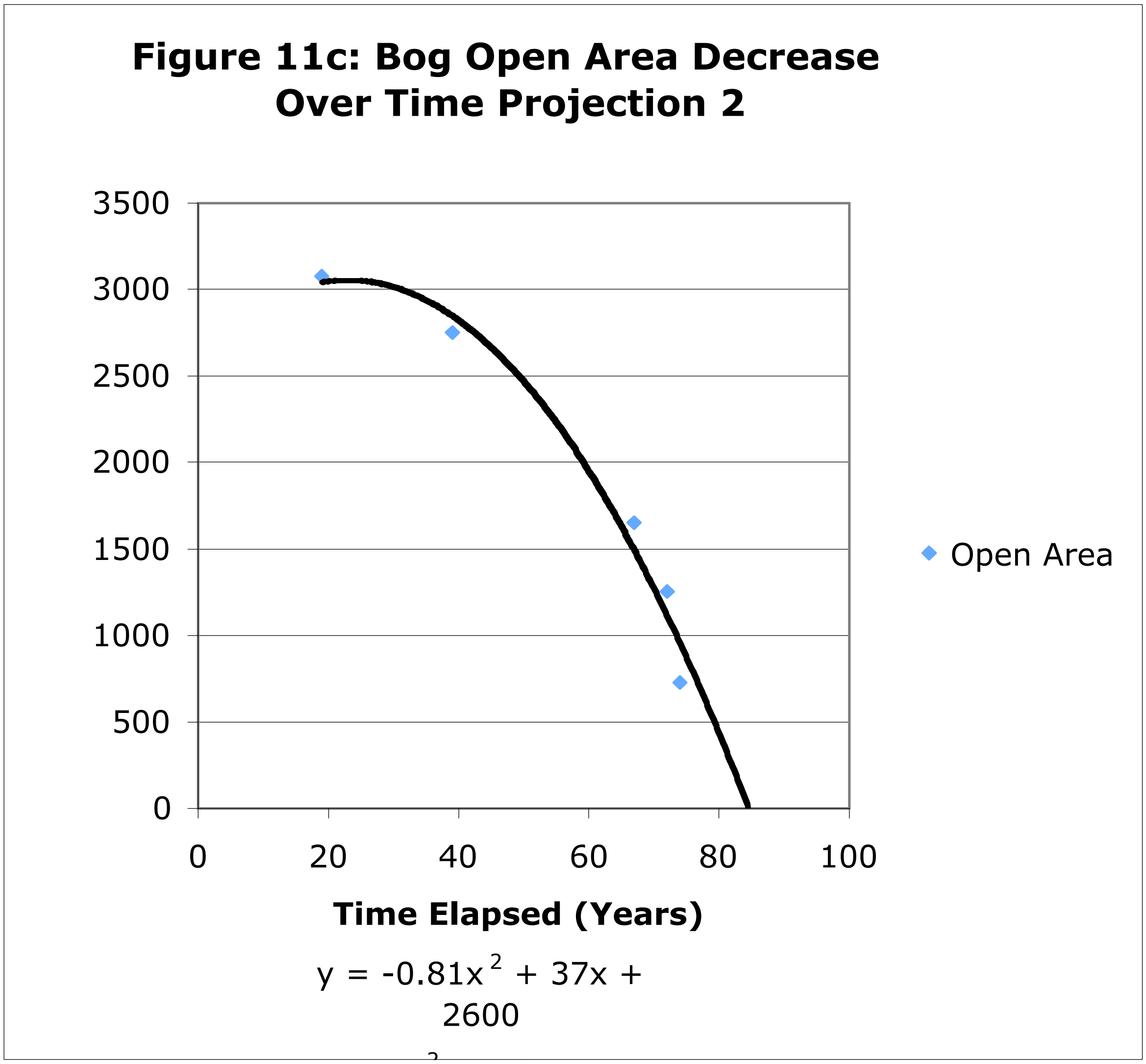

Figure 11c shows the decrease of open bog area over time with the estimated area in 1936 excluded. Removing this point provides a closer look at only the more recent data. The decline in this projection can be modeled by the line y= $-0.81x^2$ = 37x + 2600. This model shows the open area disappearing at an accelerating rate, and vanishing completely in 2019.

These different projections offer different timelines, or predictions, for the disappearance of the open bog in Fiddler's Green. The different curves give a possible window for the disappearance of the open bog, ranging from 2019 to 2040 (Figure 12).

Figure 12: Possible Window For Disappearance of Open Bog

Bog Area	Time Elapsed (Since 1936)	Corresponding Year	Projection
0	97.7	2033	9a
0	104.8	2040	9b
0	83.9	2019	9c

Figure 12 shows the several possible timelines for the bog at Fiddler's Green based on projections 11a through 11c. These models give a window of 2019 to 2040 for the disappearance of the open area of the bog.

Given previous studies on bog ecology, the rate at which a bog becomes forested tends to accelerate over time. Pioneer species, in the case of Fiddler's Green white pines and eastern tamaracks, encroach on the open area of the bog, drying it out and lowering the water table, which, in turn, encourage further forestation of the area. A curve modeling this trend would be most similar to the projection shown by Figure 11c, indicating that the open bog in Fiddler's Green may disappear sometime in the near future if natural succession continues unabated. The linear decrease shown in Figure 11a and Figure 11b is probably not a good indicator of the rate of open area decline given previous studies on bog ecology. Additionally, the data from the most recent years suggest the succession is accelerating, indicating that the open area will disappear sooner rather than later.

pH Data

The pH data show that the bog soil has not been altered drastically due to the invasion of pioneer tree species. Over time, these species would change the soil by drying it out, excluding *Sphagnum*, making the soil more basic (Miletti et al., 2005; Clymo, 1984; Rigg, 1940). Miletti et al. (2005) found pH values as high as 7.41, which indicated abnormal bog conditions. The fact that pH did not steadily increase as soil samples were taken from forested area is a positive sign for the bog in Fiddler's Green. Additionally, no sample had a basic pH, indicating that bog conditions have not been lost due to the encroachment of pioneer trees. These data suggest that the bog in Fiddler's Green is still in good health, in that the bog contains normal bog-like conditions due to extensive *Sphagnum* cover, even into the forested area.

The pH data and open area decline data together offer both optimistic and concerning data. The pH has not risen drastically form normal bog levels (Miletti et al., 2005). However, the bog is not resisting invasion of pioneer species. The physical conditions demonstrate that the bog is in good health and functioning as a true bog, indicating restoration attempts are not yet necessary. Instead, the most pressing concern is the invasion of pioneer species and the consequential shrinking of the bog, which can be solved with active management.

Pioneer Species Categorization

Most of the pioneer tree species in the bog are white pine (64%) and eastern tamarack (29%) (Figure 9). These data support previous studies classifying pines and tamaracks as pioneer species. Furthermore, these data show that pioneer species have substantially invaded the bog, and may continue to do so in an accelerating fashion unless succession is slowed.

The most densely invaded areas of the bog are located on the western half of the bog (Figure 10; Figure 4). The most heavily populated groves were in the northwestern section if the bog and extended down to the southern part of the bog (Groves 1-6, 16-22; Figure 4). The average DBH values in these groves show that they are comprised of many smaller pioneer trees, which also means that these dense groves are probably younger, and are more recent invaders of the bog, indicating that succession has occurred in these areas more recently. Additionally, some trees have established groves further into the bog than surrounding groves (Groves 7, 10, and 14; Figure 4). These groves, along with the most densely colonized areas on the whole western and southern edge of the bog should be prioritized for management. The trees in these groves are not excessively large, so clipping and removing them should not be exceedingly difficult.

Future Management and Additional Measurements

If the bog at Fiddler's Green is to be maintained in a healthy state, one important step to take will be the management of the woody pioneer species invading the bog. In the case of Fiddler's Green the most important species to target are the white pines and eastern tamaracks.

Of the previously discussed management tactics, physical trimming and/or removal of the pioneer species make the most sense for the Fiddler's Green bog. This technique targets specific unwanted individuals with the least amount of additional negative impact. The western and southern edge and northwest corner of the bog, as well as the few small groves that have moved well into the open bog space, should be the initial target areas (Figure 13). Tree management would only require a small group of people using hand tools to trim and cut trees and uproot the stumps if deemed necessary. This effort would set succession back a number of years, and would help to ensure the open bog area lasts.

Additional management strategies could be incorporated into one larger management plan. Small trees could be removed or clipped. Larger trees, such as those located on the eastern edge of the bog (Figure 10; Figure 4) could be cut, and the stumps could be treated with pesticides. The larger trees could also be girdled. Additionally, a burn plan, which would control more shrubs and growing saplings, could be developed and implemented. With active management the open bog can be maintained, and possibly even enlarged in the future. However, the first step should be to halt the invasion of the pioneer species that dry out the bog.

The bog at Fiddler's Green does not yet require reintroduction and replanting of *Sphagnum* moss. However, if other management techniques implemented in the near future are not successful, the bog will require *Sphagnum* reestablishment. Certain shrubs, when planted with *Sphagnum*, may help facilitate this process (Farrick & Price, 2009). If the condition of the bog continues to worsen, i.e. soil pH levels reach 7 or greater with high nutrient levels, then altering the bog hydrology could be a last resort effort to save the bog; however, this process should be delayed as long as possible and should at least wait until the hydrology of the bog is well understood. The first preservation efforts should involve the removal of pioneer species. The bog should then be monitored, and decisions made using those additional data.

In addition to the recommended management techniques further measurements should be made to better understand the state of the bog. The pH data could be expanded by targeting the pH in specific areas, such as the bases of larger white pines and tamaracks to see if the soil acidity has changed directly under pioneer individuals. The pH transects could also be extended farther into the forested area of the bog. The bog soils could also be understood in more detail by analyzing the samples for nutrients, such as Nitrogen and Phosphorous, which would further indicate the health of the bog. The contents of soil water could also be monitored. Low nutrient levels would help to confirm that the bog is in fact in good health. Finally, understanding the hydrology of the bog would be an interesting surveillance technique. How the water moves through the bog and the water table depth will show how much drainage and drying out has occurred due to the invasion of the woody tree species. This monitoring technique would be yet another good way to observe the health and changing conditions of the bog. Additionally, these data would be necessary if the hydrology of the bog ever needs to be altered in a conservation effort.

Conclusion

The Fiddler's Green bog is currently declining in size, perhaps even at an accelerating rate. If no management steps are taken the open area will disappear due to the encroachment of pioneer species. The pH measurements provide optimistic data. Besides the establishment of pioneer species in the open area, the bog appears to be in good health, containing extensive *Sphagnum* cover leading to normal natural bog conditions. Therefore, managing the bog is a feasible and worthwhile task and should begin with the removal of specific areas of invading trees.

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