Cover Page

Annual Report #5 (2020)

Crowland Mitigation through Restoration of the Tamarack Bog, Bath Nature Preserve. Summit County Ohio.

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Summary:

This report summarizes data from eight years of monitoring (2013-2020). Vegetation composition continues to reflect “Poor Fen” community structure. This has led to a request for adjustments of the targets for the wetland, as indicated in the last report. Continued monitoring of both water levels and the elevation of the floating mat indicate that the hydrologic alterations are having the desired effect. The trends in vegetation cover also indicate the effectiveness of water level increase resulting from the installation of the Agridrain system. There are substantial increases in herbaceous cover in the periphery of the wetland, and strong increases of young Green ash in the Edge and Enhancement areas. As planned, many Red Maple and Crabapple trees are falling, making room for native vegetation. Tamarack transplant trials have continued and are recommended for the upcoming season in the Edge and Enhancement zones. We have found that survival and growth are best with larger plugs and that deer herbivory is occasionally a problem. Invasive management was interrupted in the past year but will continue at an increased level in upcoming years. Visitors are using the boardwalk system to explore the site and citizen science repeat photo stations are being utilized.

Contents

1. Introduction

Preservation and enhancement of the Tamarack Bog at the Bath Nature Preserve are the goals of this mitigation agreement. A prior study of the area (Miletti et al. 2005) evaluated past changes and existing threats to this site. Drainage ditches placed in the 1960s, and consequent reduction of habitat (from 13.8 to 4.36 acres) were the primary problems for this area, along with invasion by Red Maples and European Buckthorn (crabapples were later noted as an important invader). Placement of a drainage control structure (Agridrain) and control of invasives are important elements of the restoration plan. The bog contains several state listed species (e.g., *Carex atlantica* var. *capillacea*, *Larix laricina*). This report provides monitoring information based on the first eight years of the restoration effort (2013-2020), with an emphasis on results acquired in 2019-2020. In addition, our recommendations for updating the targets for the project are presented in “Target Goal Adjustment” (section 6).

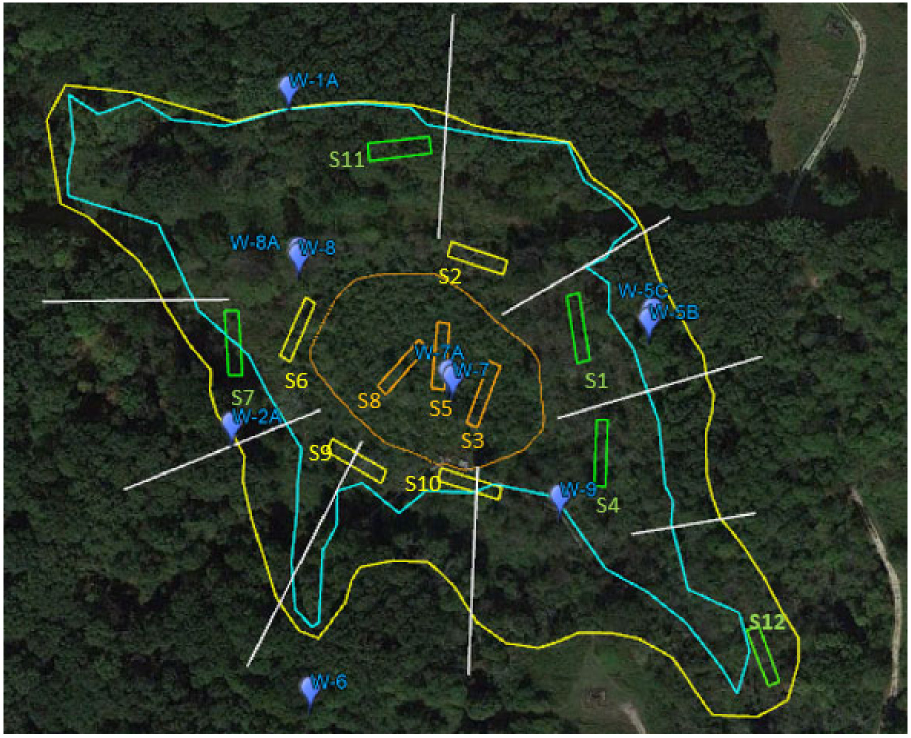

Figure 1. ***Locations of major landscape and monitoring elements of the Tamarack bog restoration.*** *The irregular yellow line surrounding the area is the target wetland extent expected following a successful restoration, the irregular blue line indicates the wetland boundary as delineated in May 2013, and the irregular orange line indicates the approximate 2013 location of the “Core Bog” plant community. Rectangular boxes indicate the 11 VIBI modules (each 25m x 5m); the orange boxes are ‘Core’ modules, the yellow boxes are ‘Edge’ modules, and the green boxes are ‘Enhancement’ modules. Plot "S12" is newly added in 2019.The 8 white lines indicate the vegetation transects. The blue points and lettering indicate water monitoring wells referred to in the text. This image shows portions of the boardwalk (installed 2015) in the center- south.*

2. Hydrology.

Water Chemistry.

As required by the mitigation agreement, we have continued yearly monitoring of the groundwater wells established in 2013. Specifically, we sampled water chemistry and levels: June 2014, November 2014, April 2015, October 2015, June 2016, June 2017, June 2018, and May 2019. Chemical analyses from these samplings are presented in the Appendices of this report, and are holding steady. In June 2020 we requested and received permission from Ohio

EPA (Thomas Babb) to be released from future ground water monitoring at the bog, based on the stable and healthy data in samples since 2013, and categorization of the wetland as a Weak Fen.

pH and Conductivity

During each of our water chemistry sampling events, we recorded field values for pH and conductivity from the wells, from the Agridrain (outlet), from the water inlet (Tributary 4), and, when possible, from the source of Tributary 4 (which is a spring ~400 m uphill to the north). Those data are shown in the graphs below (Figure 2), with the sites identified by well number, and grouped by the landscape location of the sampling point.

Across the 8 sampling events, pH was generally higher in the tributary stream and upland sites, lower on the edge and mat, and variable at the outlet. We did not detect any trends over time for any of these sampling locations.

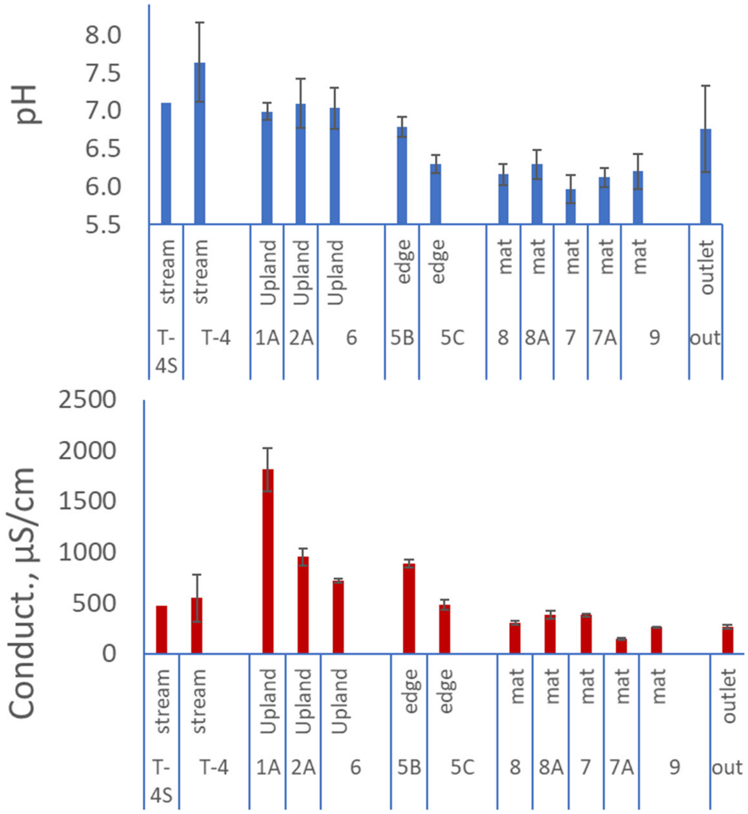

Figure 2. *Summary of pH and conductivity measures over 8 sampling sessions (2014-2019). Values are Mean ± SD over 8 yearly sampling events.*

Conductivity, which is a proxy for total dissolved solids, showed consistent readings at each site, with much higher levels for upland wells, and low values for the mat and outlet. These values confirm and extend those reported in the Mezentseva (2015) thesis that established that the wetland is a Weak Fen.

Spatial Variation in Soil pH.

Preliminary investigations explained in the 2018 report revealed interesting spatial patterns in pH across the wetland. A University of Akron Honors student is currently investigating this, and will have a full report by May 2021. Results so far confirm initial indications of both temporal and spatial variation.

Water levels in the permanent wells.

Water levels in all the wells since their establishment in 2013 are reported in Figure 3. As in the past, water levels in the main wetland area (Wells 5B, 5C, 7, 7A, 8, 8A, 9) hold steady just below the bog surface for most of the year except in the spring flood. Broad patterns over the

8-year period show rising groundwater levels from October – April, with decline through the remainder of the year

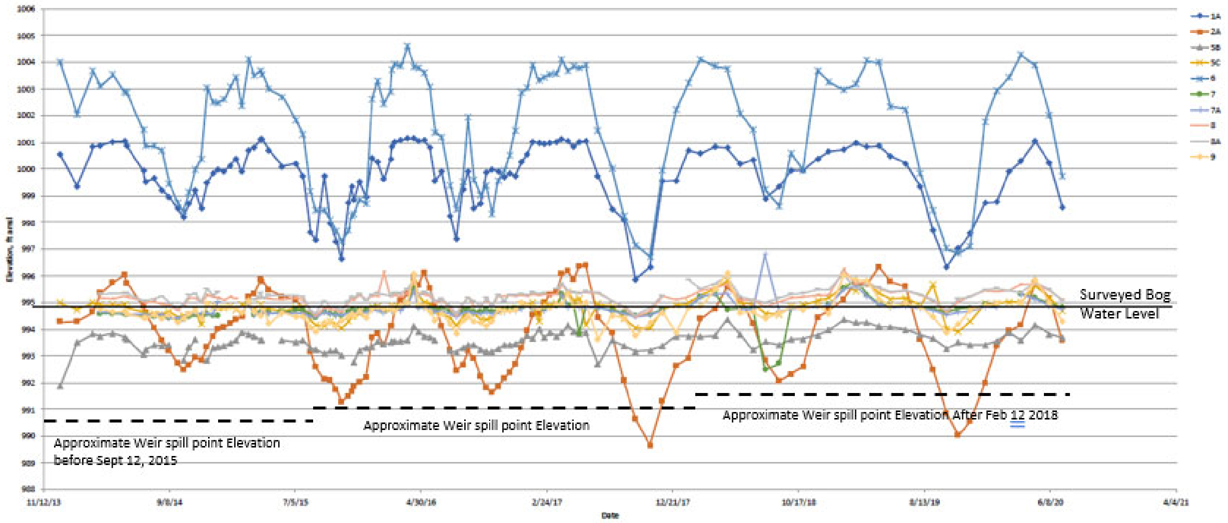

***Figure 3. Water levels in monitoring wells**, in feet above mean sea level, from December 2013, to December 2020. Note repeated cycle of rise in fall and winter, and decline through summer*

Raising the Bog Water Level.

One of the most important aims in this project is to restore the hydrology to what it was before the ditches were established in the mid-1960s (Miletti *et al.* 2005). After careful evaluations of all data in the initial report and gathered in this project, and discussion among all participants, on September 12, 2015, and again on February 13 2018, the v-notch stoplog was raised by placing additional boards in the Agridrain, increasing the outlet height by 5 ¾" both times (total outlet elevation change of 11.5"). The stoplogs also function, with an additional pressure-transducing datalogger, as a weir, allowing automated monitoring of discharge from the bog. The response to the second water level change is satisfying (see Figure 3 and), and we feel that the current level is appropriate for a successful restoration.

During the very wet spring and early summer of 2019 we became concerned that the persistence of 1-2' of standing water (above the level of the mat surface) over several weeks might harm the wetland. We discussed this Jim Bissel (CMNH), and also confirmed through direct observation that this was not a problem for the wetland.

Outlet Water Elevation and Rainfall

We have continued recording water elevation daily at the bog outlet with a pressure-transducing datalogger, and tracked rainfall from our nearby weather station. Personnel and other challenges resulting from the COVID pandemic have prevented us from providing a summary figure of those data for this report, but we will continue our monitoring, and will provide a full summary in our next report.

The Bog Mat Floats

As documented in previous reports, in 2015 we established fixed elevation poles that allowed us to monitor elevation changes of the peat/muck mat of the wetland. By measuring the height of the mat relative to those poles we can monitor any ‘floating’ of the mat ("mooratmung") driven by changes in the underlying water level. In Figure 4 we summarize all mat height measurements since installation).

These data indicate that the mat is floating relatively freely. During spring floods, the mat rose to as much as 3.04” above the arbitrary initial height, and during summer dry spells it sinks to as low as 2.96” below the initial height, for an overall amplitude of 6” so far. That range has reduced slightly since the addition of the second stoplog (-2.22 to 2.75" vs. the values above). Mean height has increased slightly since Feb 2018 (0.51" through Feb 2018, and 0.60" since then). These patterns suggest that with the current stoplog height the mat still floats freely and is unlikely to be completely submerged except during the spring-time melt. Based on these data and on vegetation responses we do not see a need to raise the stoplog further, but are willing to do so if EPA or USACE feel it is advisable.

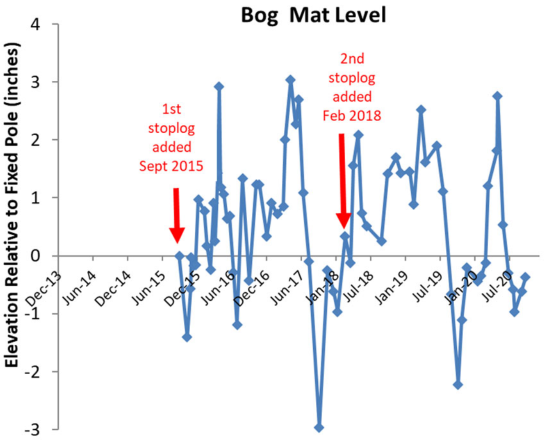

Figure 4. Bog mat level relative to fixed elevation pole. N=4 readings per data point; the data points are the means of the relative heights of 2 permanent marks at 2 stations. Last reading in December 2020.

3. Vegetation Monitoring

VIBI Modules- Methods.

As in past years we used a modified VIBI methodology (Mack 2004) to evaluate wetland quality. Methods follow those in the 2013 report – we repeat those here for convenience). Our modifications largely involve the shape of individual modules to accommodate the challenging terrain, thick shrub vegetation, and sensitive habitat (especially in the core bog area). We modified the standard 10mx10m VIBI module layout to a 25m long access lane from which we sampled a 2m width on either side of this lane. This design minimized trampling while allowing good access to the 4mx25m (100 m^2) sampling area.

We established 11 such modules (Figure 1): 3 in the Core bog area, 4 adjacent to the wetland Edge (near the delineated boundary of the wetland), and 4 that are potential areas of wetland Enhancement. Our intent was to: 1) use the Core modules to evaluate whether the existing bog maintains its status during the restoration. 2) use the wetland Edge modules to evaluate whether conditions at the Edge improve (e.g., spread of *Alnus incana, Larix laricina, Osmunda cinnamomea* and other key wetland species). 3) use the Enhancement modules (which generally had a noticeably peaty soil with a ‘bounce’, and seemed likely to improve if hydrology was restored) to evaluate wetland quality and the extent of responses to the restoration. We denoted each module in the field with permanent markers, and recorded GPS coordinates. We sited modules to include representative habitat of each of the areas listed above.

For some time now we have been anecdotally noting changes in the vegetation and hydrology of the area south of the main bog, just upstream from the outlet control structure. The vegetation has gotten thicker and gained both shrubs and herbs, and the area floods regularly each spring. To better assess these changes, in 2019 we established a new VIBI monitoring plot in that area (see Figure 1- the green rectangle in the lower right is the new "Plot S12"). We now have two years of data there: VIBI-F score for 2019 was 36, and for 2020 was 39.

In each module, we used standard VIBI methods to assess presence and percent cover of herbaceous vegetation, along with both percent cover and stem abundance of different size classes of woody plants. We summarized these data using the OEPA's VIBI spreadsheet calculator available online (using the 2013 version). For this report we also corrected some erroneous data entries from 2016 and 2017; these reduced some anomalously high VIBI and other scores for Enhancement plots in those years.

VIBI Modules- Results.

In 2019 and 2020 we repeated the annual sampling we have conducted since 2013, evaluating all 11 of the 100M^2 plots. We have so far identified 215 taxa in these plots (and another 72 species from the area that are not in the plots), including many peatland specialists (Table 1, Appendix A, Appendix B). We also documented substantial cover by undesirable (Red Maple, Crabapple) and invasive species (e.g., Buckthorn).

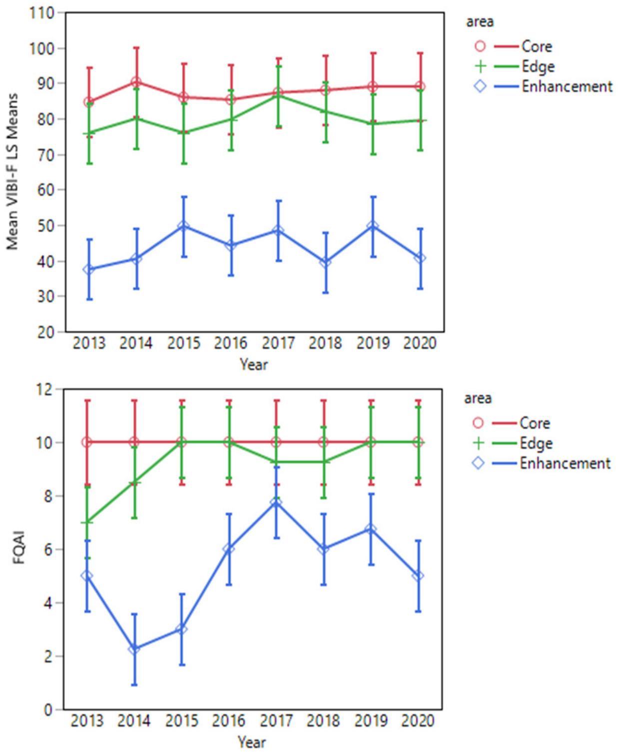

Figure 5. *VIBI and FQAI scores over time*

The plant community in the Tamarack Bog is holding steady in the higher quality areas (Core and Edge), and is improving mildly in the Enhancement areas, according to VIBI scores. Below are some summaries of our findings so far.

VIBI scores for Core and Edge plots have remained high throughout the project (Figure 6). ANOVA confirms that the different habitat areas (Core/ Edge/ Enhancement) are distinct ($F_{2, 64}$= 228, P<0.0001), and that there are no differences among years ($F_{7, 64}$= 0.8, P=0.5). Their interaction was not significant: $F_{14, 64}$= 0.6, P = 0.8).

FQAI scores are currently high and show positive trends in all areas (Figure 6). The Core area has maintained a perfect 10 throughout, and Edge areas are nearly as strong after initial improvements. The Enhancement area has improved overall. ANOVA confirms that there is a significant interaction ($F_{14, 64}$ = 2.8, P=0.02; primarily reflecting the strong increase for the Enhancement area), and that there are significant main effects of area ($F_{2,64}$= 107, P<0.0001), and year ($F_{7,64}$= 3.5 P<0.004).

Table 1. Top ten species with most cover *from VIBI plots in each wetland area during 2020. Values for proportion of cover represent mean absolute proportion cover for each species).*

Core (114 species in 3 plots)	Prop. Cover	C of C	Wetland Indicator Status
Alnus incana	0.53	6	FACW+
Moss sp.	0.46	--	--
Osmunda cinnamomea	0.29	6	FACW
Rosa palustris	0.18	5	OBL
Toxicodendron vernix	0.18	7	OBL
Decodon verticillatus	0.16	6	OBL
Symplocarpus foetidus	0.11	7	OBL
Larix laricina	0.10	7	OBL
Ilex verticillata	0.09	6	FACW+
Rhamnus frangula	0.08	*	FAC

Edge (92 species in 4 plots)	Prop. Cover	C of C	Indicator Status
Pyrus sp.	0.28	3	[UPL]
Symplocarpus foetidus	0.23	7	OBL
Carex lacustris	0.18	5	OBL
Fraxinus pennsylvanica	0.17	3	FACW
Glyceria striata	0.13	2	OBL
Pilea pumila	0.13	2	FACW
Ilex verticillata	0.13	6	FACW+
Onoclea sensibilis	0.06	2	FACW
Osmunda cinnamomea	0.06	6	FACW
Leersia oryzoides	0.06	1	OBL

Enhancement (92 species in 4 plots	Prop. Cover	C of C	Indicator Status
Carex lacustris	0.37	5	OBL
Fraxinus pennsylvanica	0.27	3	FACW
Acer rubrum	0.12	2	FAC
Pyrus sp.	0.11	3	[UPL]
Carya ovata	0.10	6	FACU-
Acer saccharum	0.09	5	FACU-
Leersia oryzoides	0.07	1	OBL
Impatiens capensis	0.06	2	FACW
Pilea pumila	0.06	2	FACW
Ulmus americana	0.05	2	FACW-

Among other metrics, we note that SVP (Seedless Vascular Plants) in the Enhancement area have been declining since 2017 (from 6 to 2 species on average); we believe this is largely a result of increased growth by graminoids that outcompete ferns. Indeed, during that time period the "Carex" metric (N *Carex* species) in the Enhancement area has steadily increased from a mean of 3.5 to a mean of 5.25

There are strong differences in the dominant species in the different wetland areas. The species with the most cover in the Core continue to be Obligate and Facultative Wetland Plants with high C of C (Coefficient of Conservatism) values, with the exception of *Rhamnus frangula,* an invasive species. The Edge area shows a similar pattern of wet-loving plants and high C of C. However, crabapples (*Pyrus* sp.), are upland plants but are the most abundant species here. Although there is extensive mortality of *Pyrus* around the wetland, coverage in our monitoring plots has not yet changed appreciably, and we will reemphasize control efforts in those areas.

The Enhancement area shows a distinctly different pattern, with fewer OBL and FACW plants, and generally lower C of C. However, over time the dominant species in this area have been shifting to become those with wetter indicator status (Table 1). Turnover from 2018 to 2020 in the Enhancement and Edge areas was high (3 of 10 species; only 1 species turnover in the Core). Note that turnover between 2016 and 2018 in the Enhancement area was 7 of 10 species). We interpret this to indicate that vegetation in these areas is still changing in response to the changed hydrology

Cover for the major invasive and problem species has strongly decreased over the last 8 years (Figure 7). Most of this decline is in Crabapples (*Pyrus* spp.) and Red Maple (*Acer rubrum*), which have dropped from 25-30% cover to about 10-15% cover. This reflects vigorous and focused control efforts (mostly girdling) by Davey Tree, and an improved method of girdling since 2016. Buckthorn (*Rhamnus frangula*) and Multiflora Rose (*Rosa multiflora*) are maintaining near the levels of 2018, with no dramatic increases or decreases.

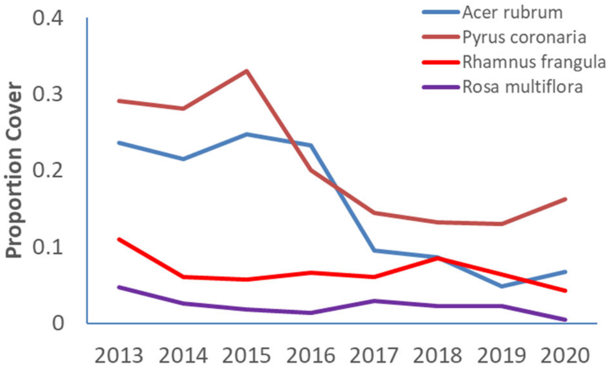

***Figure 6. Vegetative cover for major invasive** and problem species since project initiation*

Other invasives (e.g., *Phragmites* and *Phalaris arundinacea*) are present, but are not common or increasing. The only *Phragmites* in the area is in the gas line, where it is being aggressively sprayed by Davey Tree. Reed Canary is uncommon in most areas of the restoration (<1% cover total in VIBI plots).

Woody Stems

Woody stem counts in the VIBI plots document a strong increase in Native shrubs and trees. Woody stem counts are well over the target of 400 stems/acre (988 stems/Ha) overall (Figure 7), and in each of the management areas (Figure 8). In these figures, "unwanted" includes invasive woody species, along with native species not desirable in this habitat such as *Pyrus* sp., *Acer rubrum*, and *Prunus serotina*). In 2018 an unplanned change in scoring of 'clumps' (since corrected) for species such as *Rosa palustris* and *Rosa multiflora* caused a dip in woody stem counts; our experience (and data on % cover) indicate that this did not reflect an actual or worrying decrease in stems. Overall, the trajectory of woody plants across all areas is encouraging, with natives tending to hold steady or increase, and invasives decreasing.

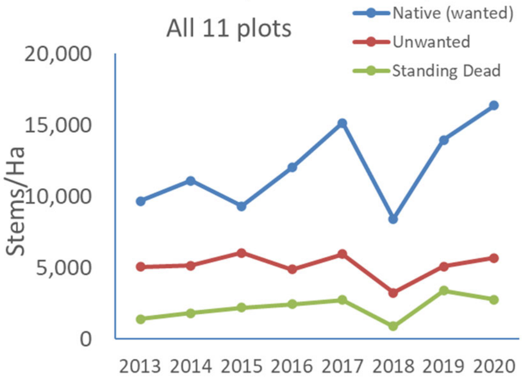

***Figure 7.** Woody stem density over time for the Bath*

Separating out these general trends by management area is illuminating (Figure 8). Note that the Core area is holding steading well above 20,000 stems/ha of native woody stems, and the other two areas are showing strong increases in native woody stems. The Edge area is also now over 20,000 stems/ha, with a strong uptick in *Ilex verticillata.* The Enhancement area is over 6,000 stems/ha, showing an abrupt increase (especially in *Fraxinus pennsylvanicus*) in the last two years, perhaps in response to hydrological changes. Unwanted woodies (*Pyrus* sp*., Acer rubrum, Rosa multiflora, Rhamnus frangula, Lonicera* sp. and some others) are not increasing. Control efforts for these species have increased, and although larger individuals of these species (primarily *Pyrus* sp., *Rhamnus frangula*, and *Acer rubrum)* are being killed, there is sufficient resprouting to make up for that. It is worth noting that the raised water level seems to have encouraged many trees (mostly *Prunus serotina*, and *Acer rubrum*) in the enhancement area to topple over (see the "Vegetation Changes" section below). Furthermore, Emerald Ash Borer damage has resulted in many large but dead *Fraxinus pennsylvanica* (see figure 17). Standing dead are holding steady.

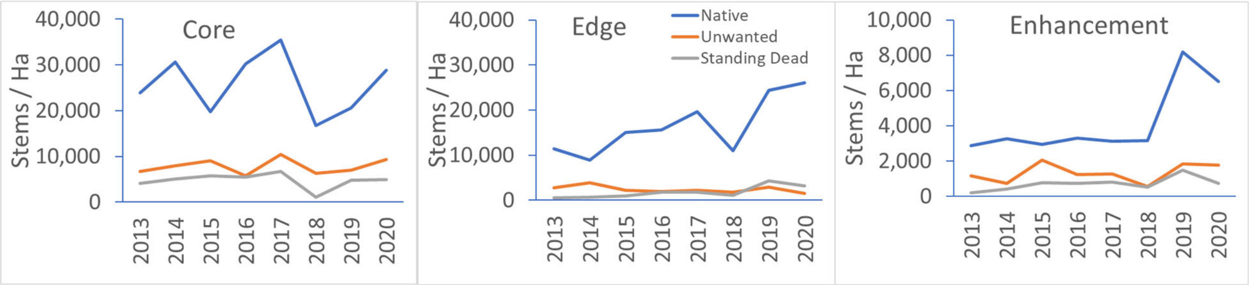

Figure 8. Woody stems for Native, Unwanted, and Standing Dead *over time. N-11 plots each year. Note different vertical axis scale for the Enhancement area.*

To further investigate the underlying patterns in these trends, we conducted a community ordination, using all 8 years of surveys in the 11 VIBI plots, for woody stem counts only. We used a Non-Metric Multidimensional Scaling analysis to generate Figure 9. This analysis represents similarities in species composition and abundance in two condensed axes. Each point in this Figure indicates a particular plot in a particular year (N= 8 years * 11 plots = 88). The points are color coded by their position in the restoration area. Points that are close together are more similar to one another in terms of community composition, and those that are far apart are less similar. Higher values on Axis 1 largely reflect the presence and abundance of typical 'core' species like *Alnus, Ilex, Larix,* and *Toxicodendron*), with lower values indicating more *Acer* and *Carya*). Axis 2 is less directly related to particular species, although *Rubus* and *Juglans* are related to high values, and *Fraxinus* to low values. The lines on the figure are 'convex hulls' that include all points of each of the three restoration habitat areas, and the crosses indicate the 'centroid' of each of the hulls. It is clear that there are strong differences in the communities in each of the areas of the bog, with a very tight similarity for those in the Core area, and a wider range in the Enhancement area. The larger range in the Enhancement area may reflect the wider range of moisture conditions among those plots.

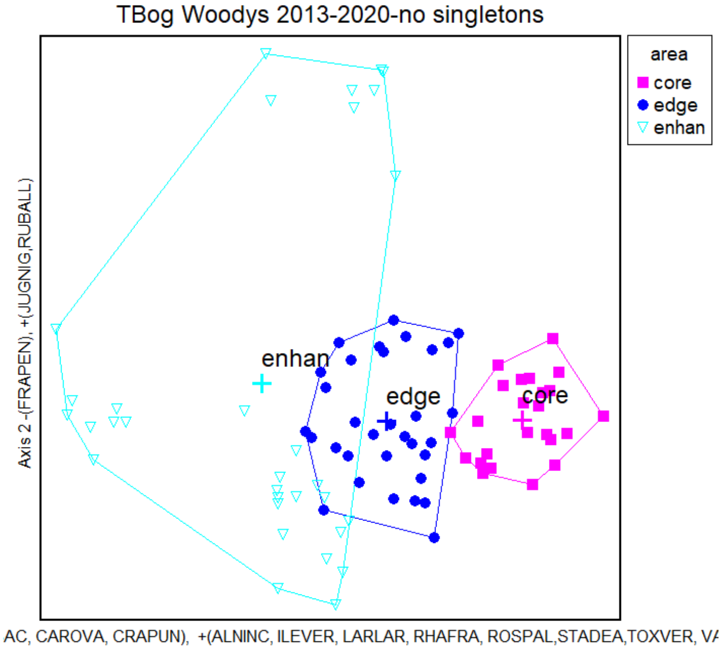

Figure 9. Ordination of woody plant community *over 8 years of sampling using NMDS. Crosses indicate centroid center, and lines are convex hulls for each habitat area's plots. NMDS analysis. Species associated with each axis are noted in axis label.*

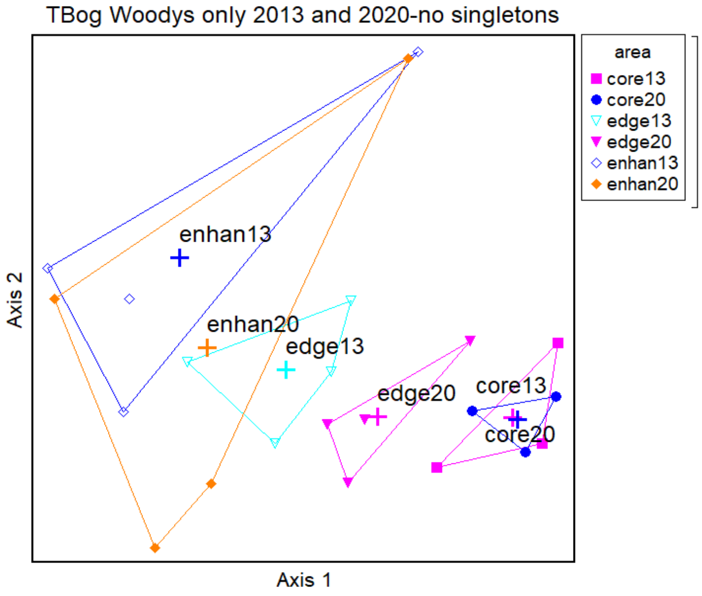

Figure 10.Ordination plot *(NMDS) comparing initial conditions (2013 to current conditions (2020) for the three habitats in the wetland. Based on woody stems. Crosses indicate centroid of each color-coded convex hull.*

To better visualize community change over 8 years, we conducted a second NMS analysis for only the data from 2013 and 2020, to compare 'before' to 'current' communities. There were only 27 species in this two year ordination, and because of the requirements of the analysis, the geometry of the figure and meaning of the axes is slightly different. Nonetheless, there are strong patterns matching those in the 8 year figure. Furthermore, there are interesting and important temporal trends to be seen here. In particular, the Core is not really changing, the Edge habitats are changing to become more like the Core, and some of the Enhancement plots are also moving toward the Core and Edge conditions. Note that the two lowest points in the orange "Enhan20" group (Enhancement plots for the year 2020) are for plots S1 and S4 – those two plots are on the far east of the wetland, where there is extensive vegetative change (increase in herbaceous cover and young Green Ash).

Vegetation Transects.

The purpose of the vegetation transects is to provide an independent method of monitoring for evidence of change in the wetland boundaries. Data are collected annually for a number of characteristics, along linear sample units, to determine if these characteristics are shifting to wetter conditions.

Eight vegetation transects were established in 2013. Each transect begins, at 0m, within the wetland and follows a compass direction (N, NE, E, SE, S, SW, W, NW) to the upland. At least 20 m of each transect is in the wetland and at least 20 m is in the upland. Some length of each transect is considered transition, where the soil or vegetation is not clearly classified. Initial transect lengths have been increased when less than 20m of the line was in wetland or upland. Vegetation, surface conditions are sampled in 10meter long intervals along the transect. Soil is sampled at the end point of each interval.

After eight years of sampling, the transect segment classifications remain consistent (Table 4) and the variability of the surface and canopy coverage do not show distinct trends (Table 3). In future reviews of this data, we will continue look for trends that indicate changes from transition to wetland or from upland to transition as evidence of increasing wetland conditions. (For example, we are watching for increases in moss cover and wetland soil characteristics in transition areas.)

Some of the changes we have noted are shown in Figures 11 to 14. We sample for the presence of unwanted or invasive species, including *Acer rubrum, Berberis thunbergia, Acer rubrum, Alliaria petiolata, Arctium* sp., *Celastrus orbiculatus, Euonymous* sp., *Ligustrum vulgare, Lonicera* sp., *Phytolacca americana, Phragmites australis, Phalaris arundinacea, Pyrus coronaria, Rhamnus frangula, Rosa multiflora, Typha spp.* The cover of these species seems to have increased in the upland zone and possibly decreased in the wetland zone. We have noticed many newly fallen trees in our VIBI plots; Figure 12 indicates this in the transects. Some of this is probably the result of management efforts, but we have also seen downed trees that were not girdled. We sample canopy cover as a way of documenting tree coverage; Figure 13 indicates a reduction in canopy cover in the wetland and transition zones. Shrub cover is also monitored; there appears to be an increase in transition and upland zones. This could be related to the change in canopy cover we have noted.

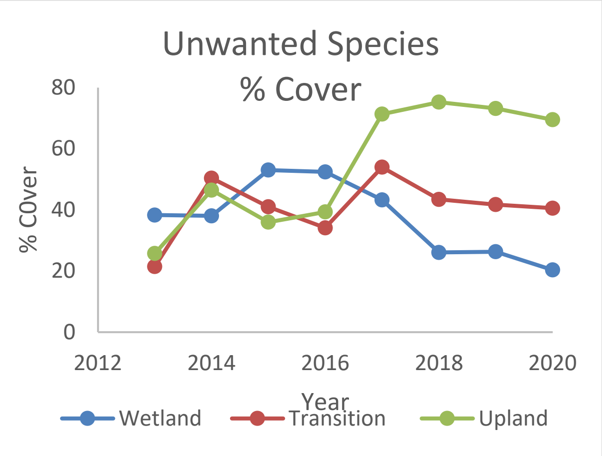

Figure 12. Changes in cover of unwanted species (transects)*. Note increase in Upland transects, possible decrease in Wetland transects, and lack of directional change in Transition transects.*

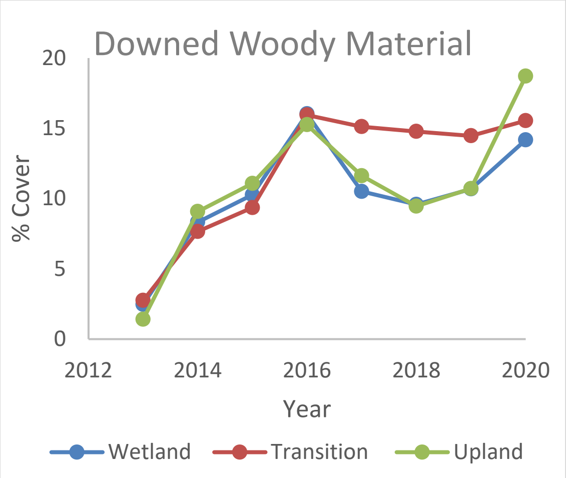

Figure 11.. Changes in cover of downed woody material Transects)*. Note increase in all zones*

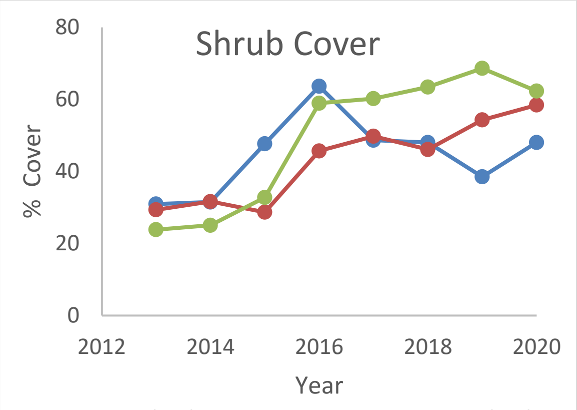

Figure 14. Change in canopy cover (Transects). *Note decrease in wetland and transition transects and lack of directional change in upland transects.*

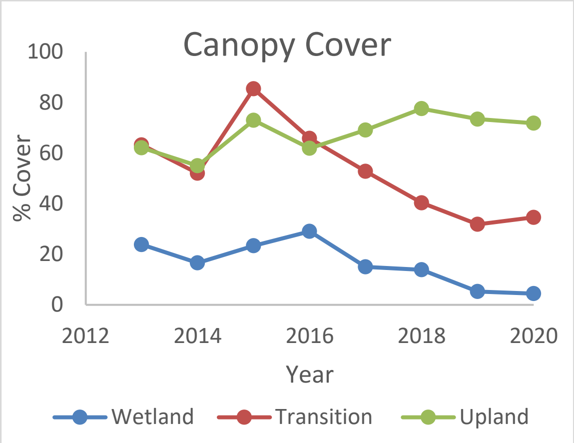

Figure 13. Change in shrub cover (Transects)*. Note trend of increase in transition and upland transects, whereas wetland transects do not show a trend of change.*

Table 3. *Average percent coverage by category and year.*

WETLAND	Litter layer	Downed woody material	Moss cover	Herb Layer Cover	Shrub Cover	Sub-canopy & pole Layer	Canopy Layer	Invasive Species Cover
2013	48.00	2.46	9.85	60.88	30.95	29.58	23.78	38.28
2014	44.02	8.32	3.29	55.44	31.50	38.90	16.54	38.02
2015	21.02	10.26	4.38	79.20	47.64	32.94	23.30	53.00
2016	30.11	16.03	4.48	72.27	63.61	27.00	29.02	52.39
2017	36.09	10.50	6.05	75.42	48.65	23.39	14.95	43.25
2018	18.53	9.58	7.41	78.00	48.00	11.72	13.80	26.05
2019	5.73	10.68	4.54	80.90	38.50	12.25	5.21	26.29
2020	27.85	14.17	8.05	88.90	48.02	9.36	4.42	20.33
Average	**28.92**	**10.25**	**6.01**	**73.88**	**44.61**	**23.14**	**16.38**	**37.20**
TRANSITION								
2013	79.50	2.75	2.25	20.17	29.33	52.67	63.17	21.42
2014	91.50	7.65	1.78	14.55	31.62	67.85	51.96	50.35
2015	82.62	9.35	1.96	37.92	28.69	67.04	85.35	40.97
2016	75.09	15.95	2.23	42.41	45.68	59.73	65.73	34.09
2017	57.86	15.11	4.24	61.07	49.73	51.57	52.71	53.93
2018	48.80	14.77	7.48	57.09	46.07	32.05	40.27	43.41
2019	26.43	14.46	3.46	77.50	54.29	41.11	31.79	41.71
2020	53.21	15.54	5.71	67.14	58.43	48.52	34.52	40.54
Average	**64.38**	**11.95**	**3.64**	**47.23**	**42.98**	**52.57**	**53.19**	**40.80**
UPLAND								
2013	68.42	1.40	3.48	31.79	23.83	48.83	62.04	25.71
2014	73.93	9.07	2.11	38.96	25.04	63.61	54.96	46.43
2015	56.07	11.07	1.61	61.39	32.75	66.89	72.93	35.96
2016	70.13	15.25	1.67	52.17	58.92	40.63	61.83	39.29
2017	69.64	11.62	2.19	44.60	60.18	58.27	69.05	71.31
2018	76.36	9.45	2.86	37.41	63.41	71.82	77.50	75.23
2019	65.54	10.71	2.39	39.29	68.59	77.93	73.37	73.15
2020	76.20	18.70	3.55	35.07	62.28	69.95	71.76	69.46
Average	**69.54**	**10.91**	**2.48**	**42.59**	**49.37**	**62.24**	**67.93**	**54.57**

***Table 4** Number of 10 m units in transect categories by year, as classified by soil inspection in field.*

Transect #	Year	Wetland	Transition	Upland
1	2013	6	1	1
1	2014	5	2	2
1	2015	5	2	2
1	2016	5	2	2
1	2017	5	2	3
1	2018	5	2	3
1	2019	5	2	3
1	2020	5	2	3
2	2013	3	2	0
2	2014	3	1	2
2	2015	3	1	2
2	2016	3	1	2
2	2017	3	1	2
2	2018	3	1	2
2	2019	3	1	2
2	2020	3	1	2
3	2013	2	1	1
3	2014	2	2	1
3	2015	2	2	1
3	2016	2	2	1
3	2017	2	2	2
3	2018	2	2	2
3	2019	2	2	2
3	2020	2	2	2
4	2013	2	2	2
4	2014	3	1	2
4	2015	3	1	3
4	2016	3	1	3
4	2017	3	1	3
4	2018	3	1	3
4	2019	3	1	3
4	2020	3	1	3
5	2013	2	1	1
5	2014	3	2	2
5	2015	4	1	1
5	2016	4	1	2
5	2017	4	1	2
5	2018	4	1	2
5	2019	4	1	4
5	2020	4	1	4
6	2013	0	3	0
6	2014	3	2	2
6	2015	5	2	3
6	2016	5	2	3
6	2017	5	2	3
6	2018	5	2	3
6	2019	5	2	3
6	2020	5	2	3
7	2013	2	2	1
7	2014	2	2	2
7	2015	2	2	3
7	2016	2	2	3
7	2017	2	2	3
7	2018	2	2	3
7	2019	2	2	3
7	2020	2	2	3
8	2013	3	1	0
8	2014	3	3	2
8	2015	3	3	2
8	2016	3	3	2
8	2017	3	3	2
8	2018	3	3	2
8	2019	3	3	2
8	2020	3	3	2

Vegetation Changes

There are four notable recent changes in the bog vegetation in the enhancement areas that are worth commenting on.

First, an expansion of herbaceous cover in the periphery of the wetland, especially in the enhancement area. A major component of this expansion is the high quality wetland sedge *Carex lacustris* (Lake Sedge; C of C=5, OBL). This species is known to thrive in slightly flooded areas (Yetka and Galatowitsch 1999), which we are now providing through the elevated stoplog at the outlet. Expansion of *C. lacustris* has been most notable in the enhancement area (especially plots S7 and S1).

Another notable (but less extensive) graminoid expansion is that of *Glyceria septentrionalis* (Floating Manna Grass; C of C=6, OBL). This species was initially restricted to the shallow ditched channel on the far east of the wetland, and is encountered frequently in the eastern side enhancement areas. It was initially absent from all plots until 2017, and is now at 0.035 cover in Plots S1 and S4.

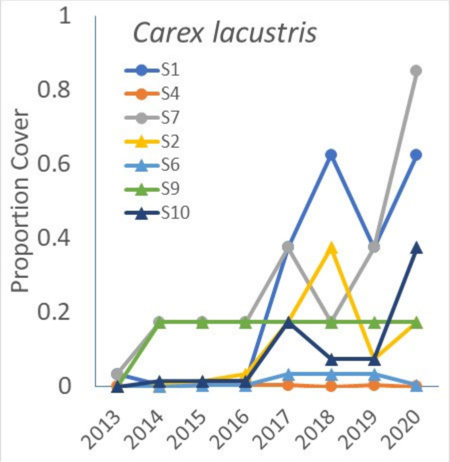

Figure 15. Proportion cover by **Lake Sedge** *in Edge plots (circles) and Enhancement plots (triangles. Lake Sedge was not present in Enhancement plot S11; and almost completely absent from Core plots).*

Second, many of the large trees in the Enhancement area are toppling over. This is in part a response to girdling efforts by Davey Tree, and in part a function of toppling by Green Ash trees killed by Emerald Ash Borer. Beyond this, however, a large portion of these are shallow-rooted trees (especially red maple and cherry) that are unstable now that water levels are higher. Often these falling trees produce large

Figure 16. Large trees are falling. *July 2019 - large red maple (~100cm dbh) fell west along the length of plot S2 (the day after we censused that plot). Not the height (over 7') and shallow nature of the rootwad, and the ~5.5' tall white plot stake alongside it.*

root wads over 6' tall (Figure 16, Figure 17). We are now working to document the increase in treefall using remote sensing image analysis.

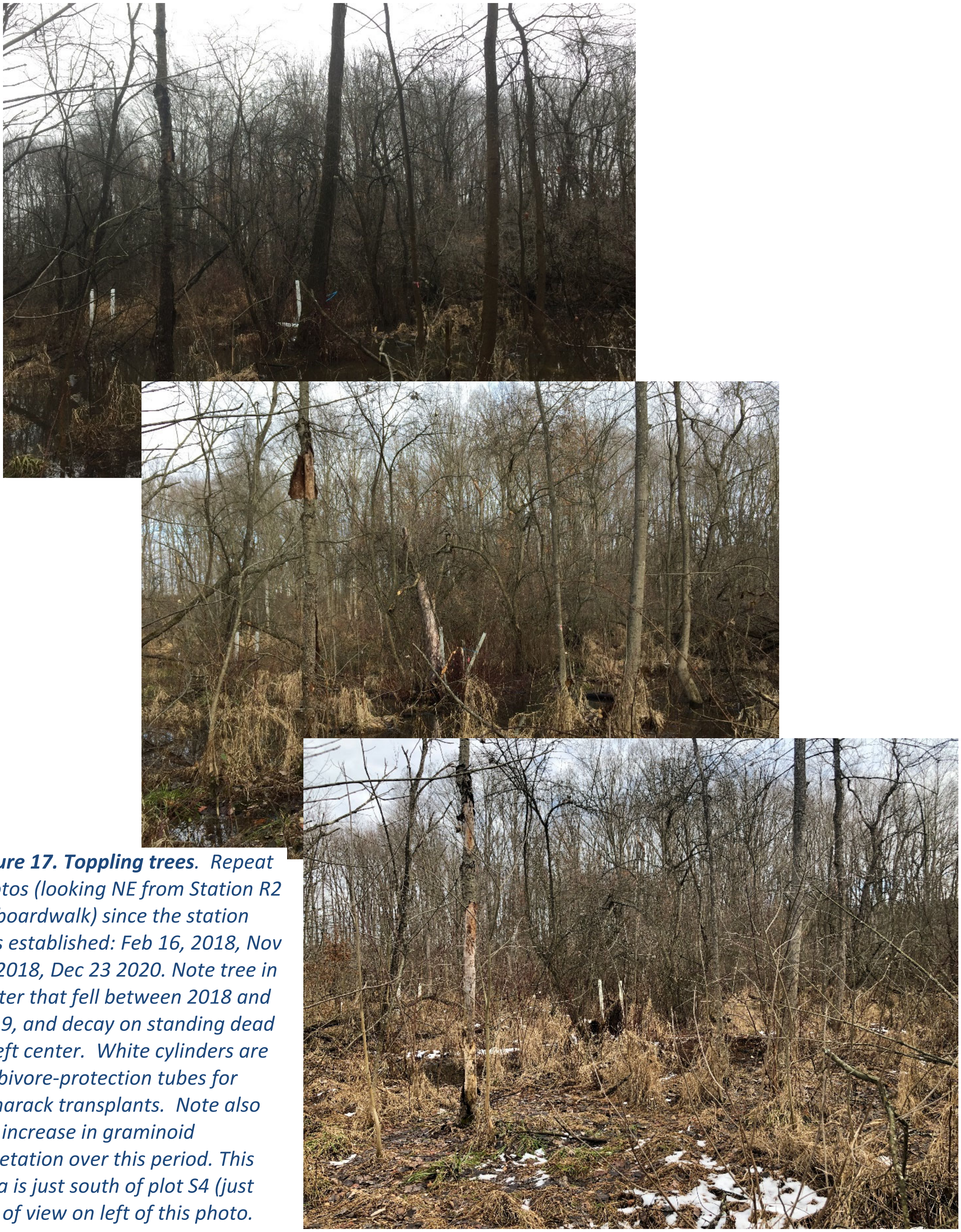

***Figure 17. Toppling trees**. Repeat photos (looking NE from Station R2 on boardwalk) since the station was established: Feb 16, 2018, Nov 21 2018, Dec 23 2020. Note tree in center that fell between 2018 and 2019, and decay on standing dead in left center. White cylinders are herbivore-protection tubes for tamarack transplants. Note also the increase in graminoid vegetation over this period. This area is just south of plot S4 (just out of view on left of this photo.*

Third, there is a strong increase in young *Fraxinus pensylvanica* (Green Ash) in the edge and enhancement areas (Figure 18). Most of this increase is in two Enhancement plots (S1, S4), and two Edge plots (S10, S2). Similar patterns apply to vegetative cover measures. We are not sure of the cause of this increase, although we have noticed similar Green Ash recruitment in nearby wetlands (and uplands) as well.

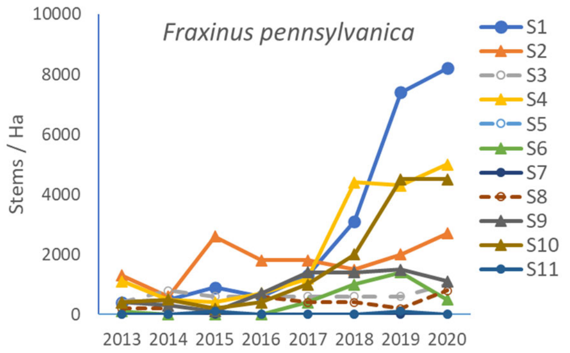

***Figure 18. Woody stems of Green** Ash in VIBI plots. Circles designate Enhancement plots, Triangles for Edge plots, and open circles with dashed lines indicate core plots.*

Sphagnum and Moss surveys

<u>Sphagnum plots.</u> To evaluate coverage and potential expansion of *Sphagnum* moss, in Spring 2014 we established 52 permanent 2mx2m quadrats (Miller 2016, Miller and Mitchell 2018). In each quadrat, we mapped the cover of *Sphagnum* moss to quantify presence and percent cover. Based on our observations during prior work we also mapped and quantified cover of the fern moss *Thuidium delicatulum*.

We were unable to sample these plots during 2019 because of prolonged flooding (comparable observations can't be made once woodies have leafed out), and also in 2020 because of the COVID Pandemic. We therefore do not have any new observations to report for moss cover. The coarser resolution information from the VIBI surveys do not suggest changes in *Sphagnum* cover overall. We plan to resume the *Sphagnum* quadrat observations this spring.

<u>Sphagnum extent survey.</u> Beginning in 2013 we recorded GPS positions for the most 'exterior' (furthest toward the upland area) *Sphagnum* clumps around the perimeter of the bog. In 2019 we found new *Sphagnum* about 5m south of the prior furthest extent, just south of the boardwalk in Plot S10.

Tamarack monitoring

<u>Adult Tamaracks and natural regeneration</u>. We have been monitoring all 8 adult tamarack trees that were noted in the bog during 2013. In 2016 we measured DBH (Diameter at Breast Height) on them, secured permanent tags, and recorded GPS coordinates so we could monitor them individually. In 2018 we noted two trees with problems. We now confirm that one of the smaller trees has died, from unknown causes. As reported earlier, one of the larger trees is still showing active woodpecker activity and holes (2-15' above the ground). As in our last report, we have not noted any new natural tamarack recruitment. All living trees continued to produce cones and seeds in 2019-20.

<u>Tamarack Transplants I.</u> In 2016 we set up a trial tamarack transplant study to evaluate methods for assisting regeneration. In June 2016 we planted 48 tamarack seedlings in the bog: 16 in each of the three regions of the restoration (Core, Edge, Enhancement). Since then we have revisited these stations at intervals, and recorded survival, herbivory, and height. The seedlings were not caged or otherwise protected from herbivores.

Although initial survival was strong, only 10% of the planted seedlings now survive, 4 years later. A large portion of this mortality came from two sources. First, the Core was just a tough place for us to plant seedlings and for them to grow. The soil is unconsolidated and often obstructed by roots, and the habitat is extremely shady. By 2019 none of the seedlings in the Core habitat survived, so 1/3 of the overall mortality (across the three habitats) is probably the result of that being a poor place to transplant. Second, there was extensive herbivory (mostly by deer) in 2016. Indeed, nearly half of the transplants suffered at least some deer herbivory in the first year. In general, plants in the Core bog had lowest survival and highest herbivory, which is mildly surprising given the very dense woody vegetation and difficult soil surface there. One aim of this trial was to evaluate whether herbivores would be an important issue for future transplants- clearly that is the case. At this point 5 of the initial 48 transplants still survive (all but 1 are in the Enhancement area).

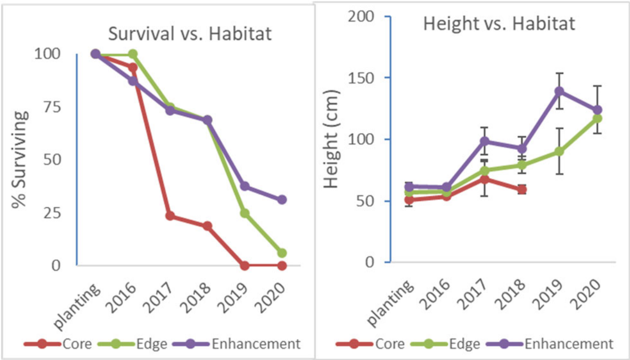

***Figure 19**. Survival and height of Tamarack transplants.*

Growth of the surviving plants in the Edge and Enhancement areas has been strong, with substantially better growth in the Enhancement areas until 2020. Plants have more than doubled in size over 4 years, and the largest transplant is over 1.8m tall.

<u>Tamarack Transplants II.</u> In 2017 an Honors student at the University of Akron (Nick Lanz) began a second set of tamarack planting trials. Based on the findings in our first year, he focused primarily on ways to reduce herbivory, and also investigated whether transplants responded to open vs. closed vegetative cover above them.

Openness. In the first of two designs, our student planted 10 groups of 9 tamarack seedlings in the Enhancement areas, where growth was best for the 2016 plantings. Half of these were in open spots (no overhanging herbs or shrubs), vs. closed spots (notable overhanging herbs or shrubs). Furthermore, in each of these plantings, 2 of the 9 transplants were enclosed in translucent 5' translucent plastic tubes (~10cm diameter) to prevent herbivory (Protex plastic Tree protector; Forestry Suppliers, Jackson, MI). We have not detected any herbivory on any seedlings from this study (whether controls, or protected by a tube).

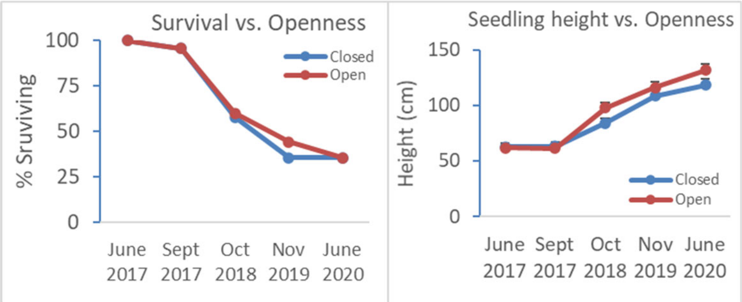

***Figure 20.** Survival and height of Tamarack II transplants with respect to openness*

Survival to June 2020 was on average 35%, and did not vary with openness (45 initial seedlings total in each treatment). Cause of mortality was not always clear, but we saw no clear signs of herbivore damage.

The surviving seedlings grew well, approximately doubling height in three years. Plants in open plots grew slightly taller than those in closed plots (132 vs 118 cm by June 2020).

Herbivore protection tubes seemed to affect both survival and height of seedlings. Note that sample size is small (only 20 total trees in tubes across the 10 plots). Survival was higher in tubes (by June 2020, 50% survived with tubes, while 31% survived without tubes). It's worth noting that survival in tubes would probably have been slightly higher, but in several cases the tube was dislodged by flooding, and pulled the seedling out of the ground. This should be preventable with more careful tube placement.

Seedlings in tubes grew to be more than 50% taller than those not in tubes (163 vs 107cm). Our impression was that the seedlings in tubes were robust, and not spindly. Indeed, one tree reached over 250cm in height and had a substantial trunk.

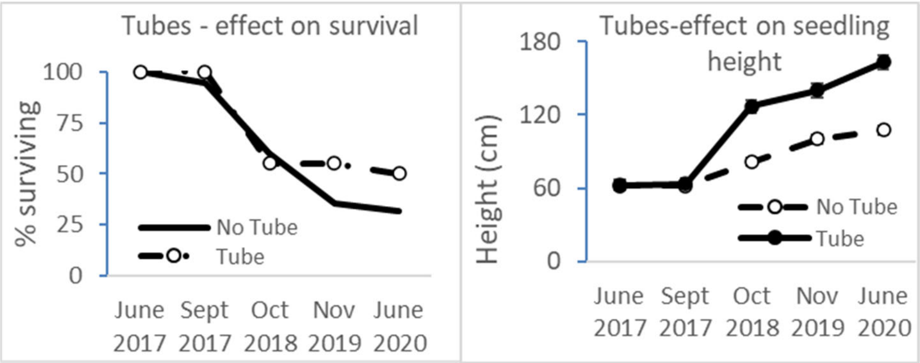

Figure 21. Survival and height of Tamarack transplants II with respect to herbivory protection via tubes

Sample sizes were too small to test for differing effects of tubes in open vs. closed plots.

Fencing. In the second design our student tested a different method for preventing herbivory - a 1m tall chicken-wire fence. He constructed 4 such fences (1.5m×1.5m) in the Enhancement area on the East side, and planted 5 seedlings inside, and another 5 outside for comparison. In contrast to our 2016 study, we did not detect any herbivory for these seedlings, whether inside outside of the fences. There was no detectable difference in height with respect to fencing, but several grew to nearly 2m by the end of the growing season, suggesting that they are establishing well.

As of Jan 2021 16/40 (40%) of these seedlings were alive (9 of 20 inside the fences, 7/20 outside). Heights were slightly shorter outside the fencing (165 ± 26 cm) compared to transplants that were fenced (180 ± 16). The tallest seedling in this experiment is now 2.9m tall. We saw no evidence of herbivory throughout this experiment, but it did appear that there was less herbaceous cover to interfere with transplant growth inside fences, and that fences may have provided some protection against falling branches from surrounding trees (a surprisingly common occurrence the last few years as girdled maples die back, ash die from ash borer, and black cherries topple over in response to wetter conditions).

Tamarack Transplants III

To further evaluate methods for planting more tamaracks, in Spring 2020 we planted 124 new seedlings (~20cm ht at planting, instead of the 50cm in past years) in the Enhancement area. By June 2020, 64 of them were still surviving (51.6%).There was a strong spatial pattern - transplants on the West side of the bog survived well (86%), while those on the East side did not

(21%). The reason for this was not immediately obvious, although some inexperienced planters had helped on the east side, and this may have reduced efficacy. Note that this difference was not evident in prior tamarack transplants in these areas (prior transplants did just fine on the east side). We did feel, however, that the shorter transplants suffered strongly from herbaceous competition on both sides of the bog, and will avoid using them in the future. Surviving plants grew equally well on both sides (June height of 24.4 cm ± 0.8 on the West side, and 22 ± 1.8 on the East)

Summary of tamarack transplants:

This table roughly summarizes the information above

Study	**Duration (Years)**	**Overall Survival**	**N now alive**	**Survival Comparison**	**Height**	**Height Comparison**
2016 Trial	4	10%	5	31% in Enhancement	110cm	tallest in enhancement.
2017 Openness and Tubes	3	35%	32	50% in tubes	120 cm	slightly taller in open 50% taller in tubes
2017 Fencing	3	40%	22	slightly better inside fence	170cm	15% taller in fences
2020 Seedling size	1	51%	64	better on West side	23 cm	no pattern

Across the studies, there are now 123 surviving transplanted tamaracks.

Plot Photos Over Time.

In 2014 we began to photograph from each corner in each of the 11 VIBI plots. We have also established photo sites at the transect endpoints. Representative photos are included in Appendix E. Those photos document a stable community in the Core bog (Plots S3, S5, S8), general improvements in the Edge area (Plots S2, S6, S9, S10), and increased herbaceous cover in Enhancement plots (especially plots S1, S4, and S7).

In April 2017 we installed four citizen science repeat photo stations along the boardwalk and have received dozens of photos from the public by December 2018. We also use those stations for our own photos and have recorded several hundred images of those same sites ourselves. The photos in Figure 15 come from one of those stations. We also include photos from another station below. These and the other photos support the conclusions reported above about the VIBI plots and Transects.

Repeat Photos Station R3 (next page). Selected photos (Extracted from Appendix E - Plot Photos) This plot in the middle of the boardwalk, looking toward the core bog. Left column is earliest available photo for each month, right column is most recent available photo. Note tamarack trees in background, and reduced cover of *Typha*.

10-Aug-2017

18-Aug-2020

19-Dec-2017

5-Dec-2020

6-May-2018

13-May-2020

4. Invasive management

Invasive management by Davey Tree has continued at the wetland. Through 2018 there had been two visits/year, and at that time we arranged for an increase to three visits/year, on the advice of Thomas Babb of Ohio EPA. However, because of a communications mixup, there was only one visit in 2019. By 2020 we corrected the error and actually got 4 treatment visits that year. The plan is to continue 3 visits/year. Treatments have targeted *Phalaris arundinacea* (reed canary grass), *Rosa multiflora* (multiflora rose), *Rhamnus* spp. (buckthorn) *Pyrus* (Malus) spp. (crab apple).and *Acer rubrum* (red maple). Herbaceous vegetation and small shrubs are treated with a foliar method via low volume backpack sprayers, containing an aquatic approved glyphosate mixture. Woody invasive trees and large shrubs receive the hack and squirt method using an aquatic approved triclopyr herbicide mixture.

In the 2018 report we noted arrival of Butterweed (*Packera glabella*), on the west margin of the restoration area. Although it is still present, and is now noticeable at other nearby areas at the Bath Nature Preserve, abundance is very low (perhaps a dozen stems in 2020). We will continue to carefully monitor this potential problem.

A summary of the Davey Tree efforts for invasive control is presented in Appendix F

5. Outreach and Access

An important part of the restoration activity at the Tamarack bog is public outreach. To that end the township installed a boardwalk in 2015-16, and interpretive signage in late 2016. In Spring 2017 we installed four citizen science repeat photo stations along the boardwalk. Use of the boardwalk has been strong, and the public seems to be engaging with the project well. We have received over 35 photos from these stations since 2018, and use them regularly ourselves.

6. Target goal adjustment

In Spring 2018 we began discussions about changing the target criteria for this restoration among all interested parties (EPA, ACOE, Bath Township, Balog, Mitchell, Hartman). A general agreement was reached that

1) The wetland is not a bog, but the criteria for a successful restoration largely assume that bog-like conditions should be established
2) The wetland is best described as a poor fen, and may have been originally an ‘Alder Shrub Swamp’ (Anderson 1982).

Mitchell and Hartman shared a specific proposal for these changes in February 2020, and are eagerly waiting for comments and potential approval. The major features of this request are:

a) Change in target vegetation to "Mixed Shrub-Swamp community" (circumneutral - a "poor fen") with a small area of Tamarack fen.
b) Eliminating the requirement to double Sphagnum coverage.
c) Request clarification of tamarack planting requirements, and an adjustment to the number of tamaracks required, to account for this being a poor fen
d) Clarification on terminology regarding bog vs other wetland types
e) Clarification that baseline year was 2013, and 2014 was year 1.

7. List of Appendices

Appendix A: Plant Species List for the Tamarack Bog as of 2018

- See attachment. Includes 293 identified species, and 30 taxa not yet confirmed to species. Voucher specimens are on file for 205 of these taxa. Total includes an initial survey of mosses (32 species).

Appendix B: Wildlife Observations at the Tamarack bog as of 2018.

– See attachment. 36 species of animals have been identified, including 8 amphibians

Appendix C: Copies of all data sheets

– see attachment

Appendix D: Copies of Water Chemistry reports

– see attachments

- Appendix D - June 2014 Chemistry
- Appendix D - November 2014 Chemistry
- Appendix D - April 2015 Chemistry
- Appendix D - October 2015 Chemistry
- Appendix D - June 2016 Chemistry
- Appendix D – June 2017 Chemistry
- Appendix D – June 2018 Chemistry
- Appendix D - May 2019 Chemistry

Appendix E: Plot Photos

– see attachments

Appendix F: Invasive control summaries

– see attachments

8. Publications to date resulting from this project

(PDFs available online, or hardcopies available on request)

- Lanz, N. 2020. Effect of sunlight exposure and herbivory prevention on growth of *Larix laricina* in Bath Nature Preserve, Ohio. Honors thesis, University of Akron.
- Mezentseva, K. (2015). Hydrology of the Tamarack Bog, Bath Nature Preserve, Bath Township, Ohio, The University of Akron. (http://gradworks.umi.com/16/01/1601098.html)

- Mezentseva, K, I Sasowsky, RJ Mitchell, J Senko, T Quick, J Rizzo, & Loucek J. (2015). Disturbed tamarack "bog" in Northern Ohio revealed as a fen. Poster, Geological Society of America meeting, Baltimore, MD. Abstract with Programs V 47, No. 7, p. 749.
- Miller, J. A. (2016). Monitoring of *Sphagnum* at a Restoration Site and Possibilities for Restorative Activities. The University of Akron. (https://etd.ohiolink.edu/pg_10?0::NO:10:P10_ETD_SUBID:115968)
- Miller, J.A. and R. J. Mitchell (2018). Source Locality Effects on Restoration Potential in *Sphagnum palustre* L. from 3 Ohio Sites. The Ohio Journal of Science 118(2): 34-42. DOI: http://dx.doi.org/10.18061/ojs.v118i2.6354

9. References

Anderson, DM. 1982. Plant communities of Ohio: a preliminary classification and description. ODNR, 184 pp

Mack, John J. (2004). Integrated Wetland Assessment Program. Part 4: Vegetation Index of Biotic Integrity (VIBI) and Tiered Aquatic Life Uses (TALUs) for Ohio wetlands. Ohio EPA Technical Report WET/2004-4. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio

Mezentseva, K. (2015). Hydrology of The Tamarack Bog. Bath Nature Preserve, Bath Township, Ohio. MS Thesis, Geology, The University of Akron.

Miller, J. A. 2016. Monitoring of Sphagnum at a Restoration Site and Possibilities for Restorative Activities. MS Thesis, Biology, The University of Akron.

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Miletti, T. E., C. N. Carlyle, C. R. Picard, K. M. Mulac, A. Landaw, and L. H. Fraser. 2005. Hydrology, Water Chemistry, and Vegetation Characteristics of a Tamarack Bog in Bath Township, Ohio: Towards Restoration and Enhancement. Ohio Journal of Science 105:21-30.

Yetka, L. A., and S. M. Galatowitsch. 1999. Factors Affecting Revegetation of Carex lacustris and Carex stricta from Rhizomes. Restoration Ecology 7:162-171.