Cover Page

Annual Report #4 (2018)

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

Prepared by Dr. Randy Mitchell and Dr. Jean Marie Hartman

University of Akron and Rutgers University

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Summary:
This project is now near its midpoint. Most of our work since the 2016 report involves continuation of past monitoring efforts. These data confirm prior findings (e.g., the wetland is best considered a "Poor Fen", water levels fluctuate on a regular annual cycle, vegetation in the Core and adjacent areas is mostly holding steady and is typical of high quality wetland). Restoration efforts in the past 2 years have raised the water level a second time (in 2015 and again in 2018; both times via addition of 5 ¾" stoplogs to the Agridrain), and include more aggressive control of invasive species. Continued monitoring of both water levels and the elevation of the floating mat indicate that the hydrological alterations are having their desired effect, but continued monitoring is required to ensure that the water level is not too high. Raising the water levels shows no signs of harming the Core and Edge areas so far. The Enhancement areas (those dryer areas that started off with low vegetation quality) are now showing signs that they are transitioning to a wetter and higher-quality plant community, as desired. Tamarack transplant trials are continuing, and most transplants in the Edge and Enhancement areas have survived and grown for 2 years. Invasive management efforts were increased from twice per year to three times per year in 2018, to deal with an increase in invasive pressure in the rapidly changing Enhancement areas. Outreach efforts have expanded to include interpretive signage and citizen science repeat photo stations. Discussions about changing the target criteria for restoration success began in 2018 and are continuing.

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1. Introduction

Preservation and enhancement of the Tamarack Bog at the Bath Nature Preserve is a goal of the 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 six years of the restoration effort (2013-2018), with an emphasis on results acquired in 2017-2018.

2. Peat/Muck Extent Survey

A survey from August 2015 (described in detail in the 2016 Mitigation Report) documented the extent of peat and muck soils in the restoration area (Figure 1). That survey found that the 2015 peat and muck distribution agree with the pre-1960 boundaries of the original wetland (Miletti et al. 2005). No updates to this in 2017-18.

3. Hydrology.

MS Thesis on Bog Hydrology and Water Chemistry.

A key element for this restoration was determining the Hydrology and Water chemistry to evaluate the current and historic status of the wetland as a bog or fen. In 2016's report we provided a detailed summary of Karyna Mezntseva's MS thesis, which concluded that the hydrology and water chemistry confirm what the plants have been telling us - this wetland is really a weak ("poor") fen. Mezentseva's 263 page thesis (Mezentseva 2015) can be downloaded as a pdf at http://gradworks.umi.com/16/01/1601098.html or is available from us upon request.

We have continued many of the same hydrologic and water chemistry measurements since then, as required by the mitigation agreement, and summarize them below. In particular, we sampled water chemistry and levels: June 2014, November 2014, April 2015, October 2015, June 2016, June 2017, and June 2018. Chemical analyses from these samplings are presented in the Appendices of this report, and are holding steady.

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.

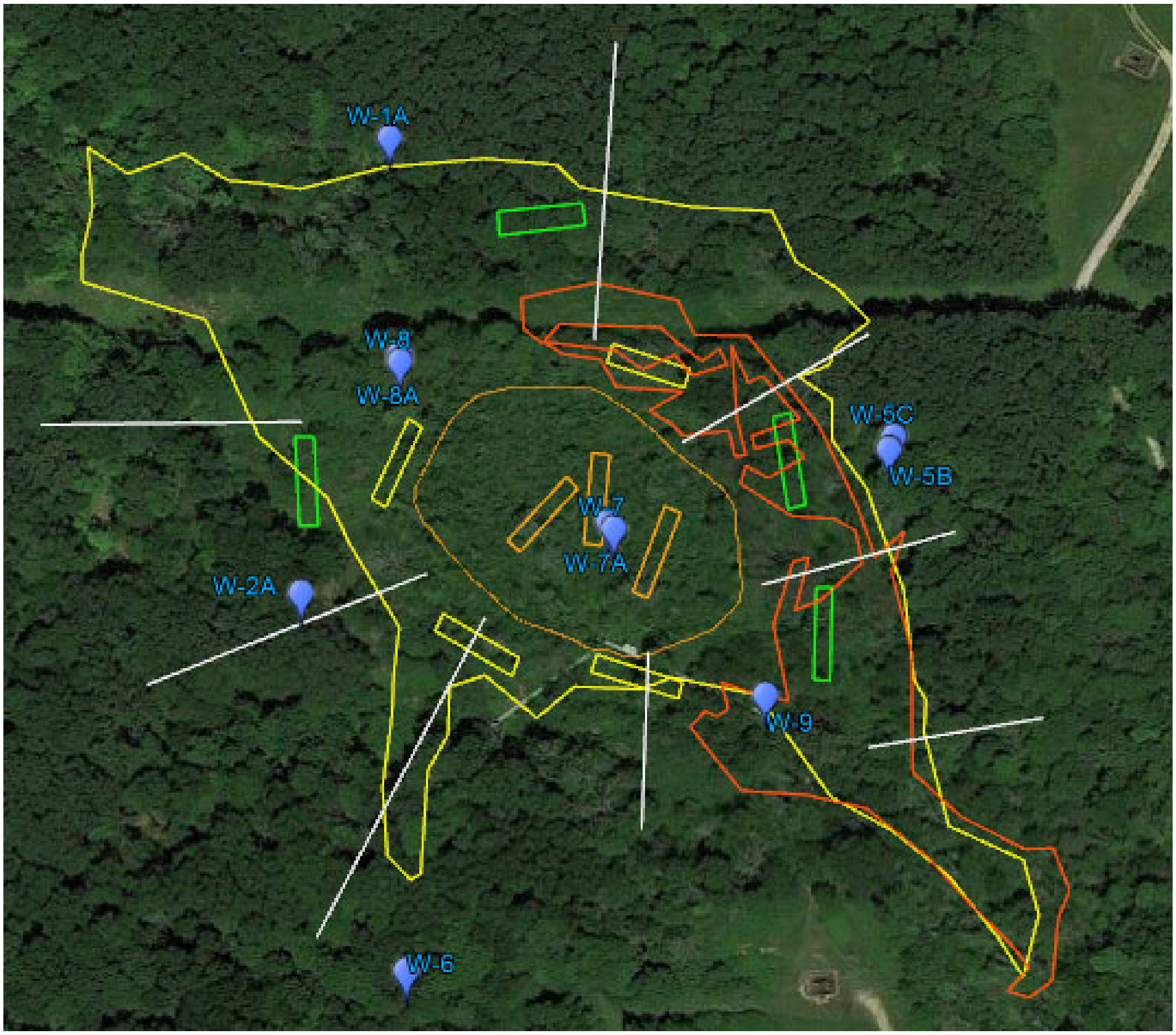

Figure 1. Locations of major landscape and monitoring elements of the Tamarack bog restoration. The irregular yellow line surrounding the area is the wetland boundary as delineated in May 2013, and the irregular orange line indicates the approximate 2013 location of the "Core Bog" plant community. Rectangular boxes indicate the 11 VIBI modules; the orange boxes are 'Core' modules, the yellow boxes are 'Edge' modules, and the green boxes are 'Enhancement' modules. The 8 white lines indicate the original vegetation transects (some have been elongated). The blue points and lettering indicate water monitoring wells referred to in the text. The red outline on the east side of the bog represents the extent of 6" or more flooding on Dec 31, 2018 (Stage gage at 1.58'). This area did not flood separately before installation of the second stoplog. The western boundary of the flooded area is not distinct and extends irregularly into the Core bog (but much shallower). This image shows portions of the boardwalk (installed 2015) in the center- south.

pH was generally higher in the tributary stream and upland sites, lower on the edge and mat, and highly variable at the outlet. Note the slight trend for decreasing pH at the margin sites.

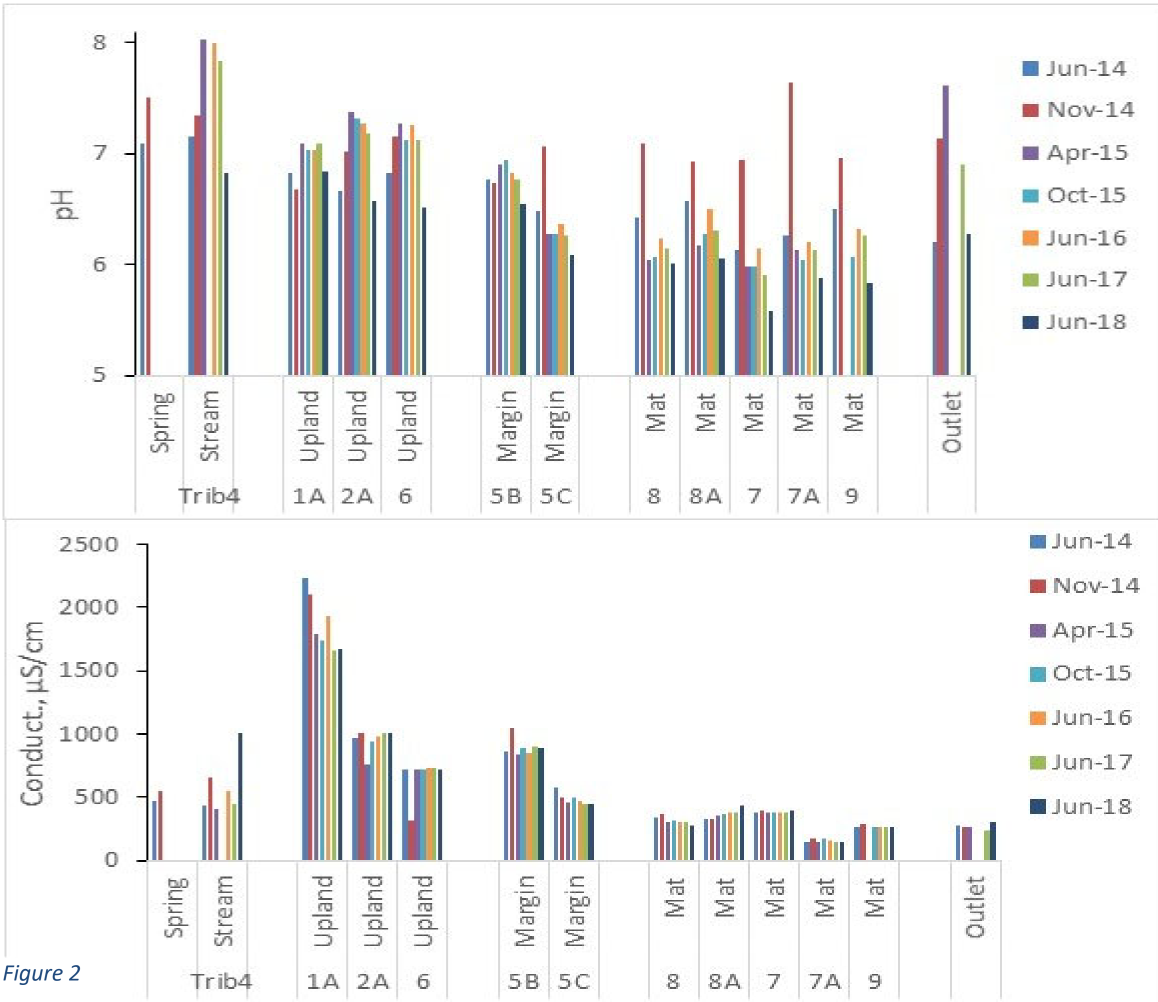

Figure 2

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.

Spatial Variation in Soil pH.

During our investigations we became curious about spatial patterns in pH across the wetland and began to investigate that. Beginning in May 2018 we periodically visited existing geo-referenced stakes (e.g, VIBI plot corners, permanent wells), and took the pH of the soil using a Hanna HI9921 direct soil pH meter. We categorized each sample location as being in one of the three regions of the restoration area (Core, Edge, Enhancement). Those results are summarized in Figure 3. We found strong and statistically significant differences in pH according to both region and time of year. The Core had the most acidic substrate, averaging below 6, while the nearby Edge was had the most basic substrate. May pH was lowest overall, and December was highest, but the rank order of the three regions did not change significantly. These results are consistent with our impression that the groundwater influence in the wetland is strongest where there is water flow (Edge), and least in the bog center (Core), allowing for acidification. This may suggest that bog specialist species face environmental challenges in the areas with higher flow. We will continue these measurements in the coming years to refine our understanding.

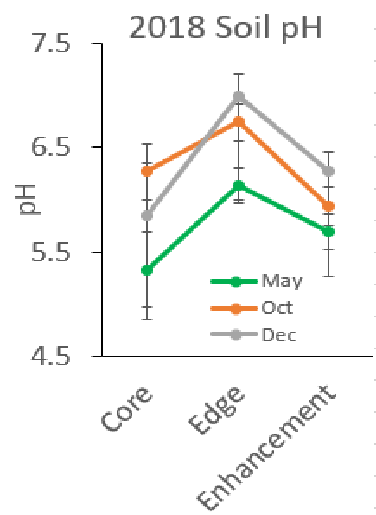

Figure3. Soil pH. N=~12/area/sampling period

Water levels in the permanent wells.

Water levels in all the wells since their establishment in 2013 are reported in Figure 4. 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 6-year period show rising groundwater levels from October – April, with decline through the remainder of the year

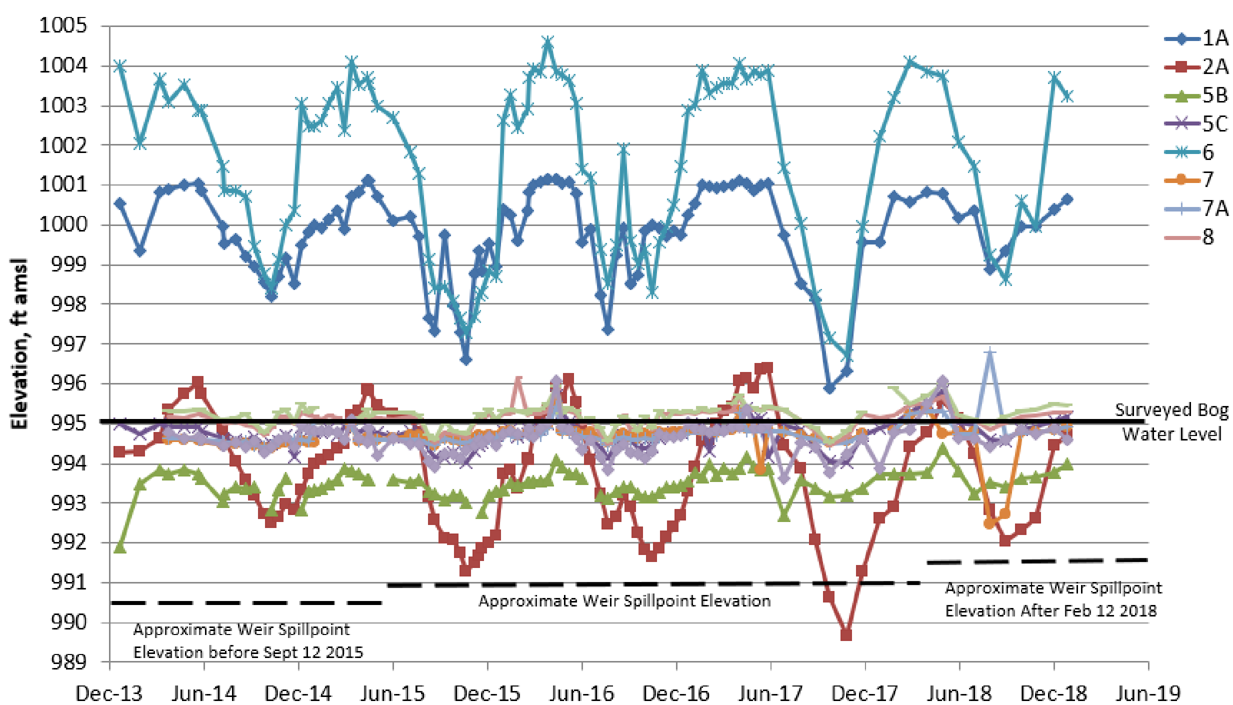

***Figure 4. Water levels in monitoring wells**, in feet above mean sea level, from December 2013, to December 2018. Note repeated cycle of rise in fall and winter, and decline through summer*

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 first water level change was encouraging (as explained in the 2016 report and below), and the team judged that another log should be added to achieve the desired change in hydrology.

Outlet Water Elevation and Rainfall

We recorded water elevation daily at the bog outlet with a pressure-transducing datalogger and tracked rainfall from our nearby weather station (Figure 5). Summer 2017 was a severely dry period for the region (http://droughtmonitor.unl.edu/Home.aspx), reflected in low rainfall and a notable dip in water levels.

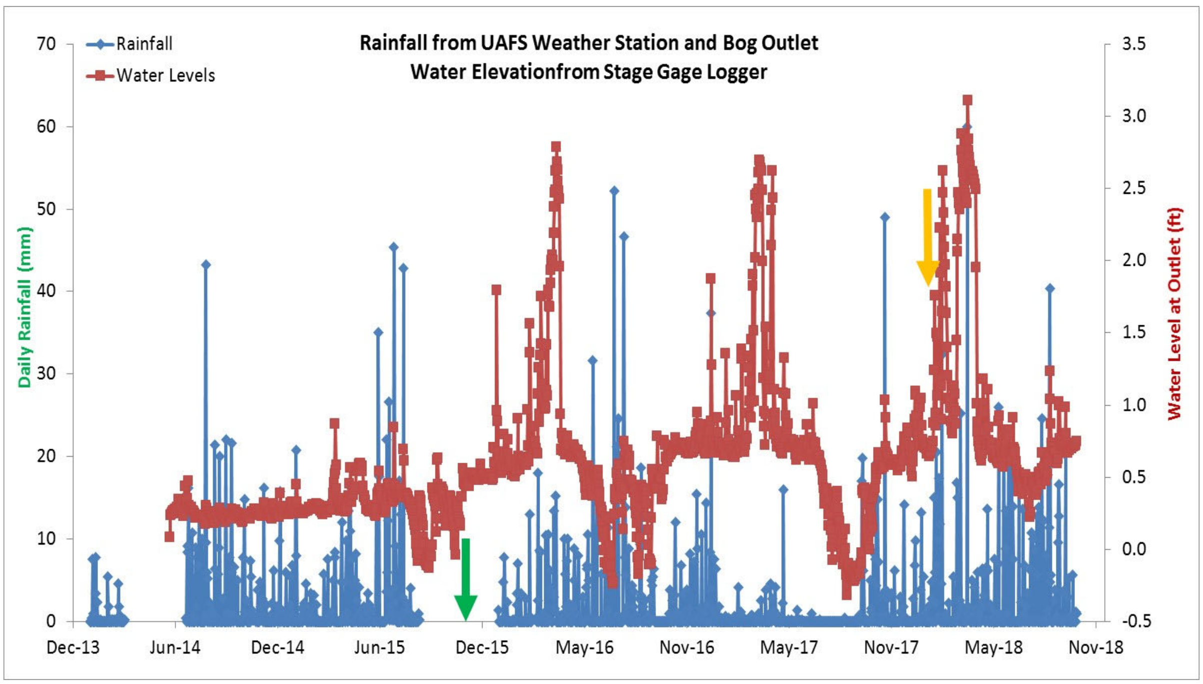

Figure 5. *Rainfall and outlet water elevation. Green arrow indicates Sept 12, 2015, when the water outlet level was first raised. The orange arrow indicates the second time the water outlet was raised, Feb 12 2018. Gaps in the traces reflect equipment malfunction*

The Bog Mat Floats

In the previous report (2016) we documented the installation of a way to monitor the elevation changes of the peat/muck mat of the wetland. We achieved this by installing two fixed elevation poles in separate areas of the wetland (at Well 7, near the center of the Bog and Well 8, near the northern edge). By measuring the height of the mat relative to those poles we could monitor any 'floating' of the mat driven by changes in the underlying water level. In the 2016 report we documented substantial changes in elevation of the mat over the season, mirroring changes in the level of water at the outlet. We have continued and will continue monitoring the mat elevation since then, and report updated elevation information in Figure 6 (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 2018).

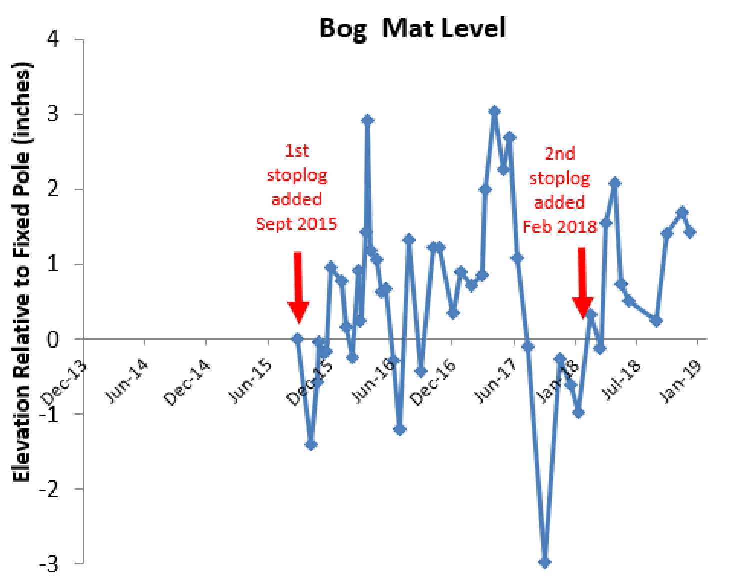

Figure 6.

The mat height measurements using the Fixed Pole method clearly 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" over our initial 39 months of measurement. This range suggests that raising the stoplog is unlikely to completely submerge the floating mat, and is one of the reasons that we added the second stoplog in Feb 2018, as recommended in the 2016 report. There are some indications that adding the second stoplog in Feb 2018 has raised the typical mat level an inch or so, but it is too early to be sure.

In December 2015, we placed a pressure-transducing logger at the well 7 fixed pole to record the absolute elevation of the water in the Core Bog. These data (Figure 7) parallel those from the mat level measurements above, documenting substantial water level variation over time (for the 45 days on which mat levels were measured, the correlation coefficient is 0.81, signifying a very strong association). The logger data also have a greater range of variation than the mat elevation changes (total range of 2.0', compared to 0.5' range for the mat), suggesting that the mat resists movement to some extent, and does not match the more extreme water level movements.

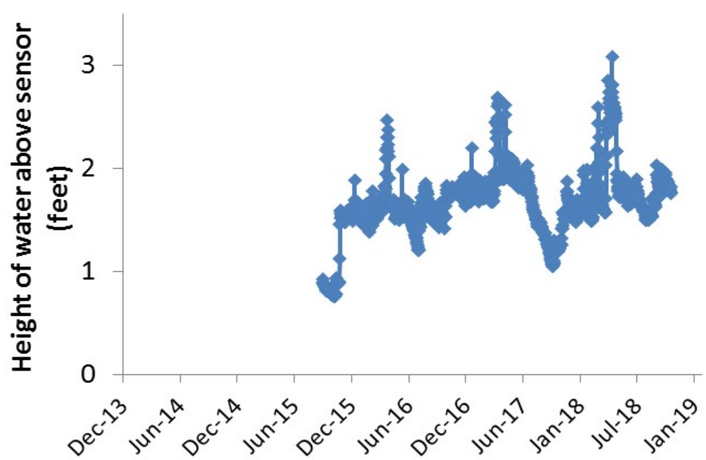

Figure 7. *Absolute height of water in central bog (Well 7)*

Although the addition of a 5 ¾" stoplog to the Agridrain twice over the project raised water levels nearly a foot, the fact that the mat floats suggests that this should not strongly affect **depth to water for wells on the mat**. That is indeed the case: (Figure 8; Before Sept 2015 N=35, Sept 2015-Feb 2018 N=54, Feb 2018-Dec 2018 N=11). All but one of the wells have water typically within a foot of the surface, with a mild temporal trend for water to be nearer the surface in the most recent interval. Well 5B has distinctly lower water levels – note that is on the wetland's NE upland edge, and is screened at 28' deep, while 5C is screened at 16'. It therefore is responding to a distinctly deeper water source than are the other wells. The other wells are largely tracking the surface water levels relevant to the vegetation in the Core and Edge bog areas. In other words, except in extreme flood events, the mat is tracking the level of water in the bog, and there should not be extensive and extended flooding of the mat in response to changes in the elevation of the outlet (within limits).

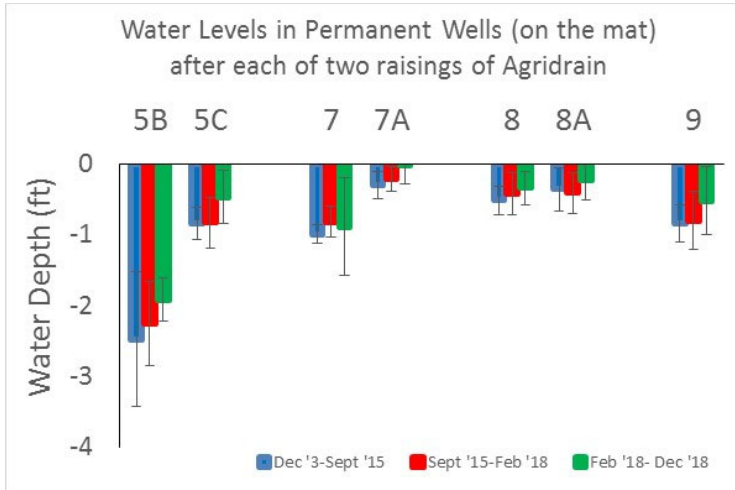

Figure 8. *Depth to water for wells on the mat*

Although the mat seems to be maintaining a fairly steady elevation above the water level, flooding on the margins of the wetland has increased, at least anecdotally. For example, during a recent winter flooding event (December 2018) we noted water levels over 16" around the southeastern and eastern edges of the wetland (Figure 1, red outline). Our impression is that the peat mat is "grounded" in this area and therefore cannot float. These wetter conditions are likely to increase the amount of wetland vegetation here, and help eliminate more upland elements such as red maple and cherry. Indeed, several 3-8" DBH cherries in this area have recently toppled over, and the repeat photos of this area (Appendix E) show an increase in vegetative cover.

Our evaluation of the hydrological situation is that the water levels at present are suitable for a successful restoration. However, we need a longer evaluation period to determine whether some fine tuning may be necessary. In particular, the flooding of winter 2018 was more extensive and deeper than expected – if this persists, we may consider dropping the water level 2-3".

4. 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 10x10m 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 4x25m 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., experience spread of *Alnus incana, Larix laricina, Osmunda cinnamomea* and other key 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.

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 have updated all prior spreadsheets to the 2013 version, to ensure comparable measures).

VIBI Modules- Results.

In 2017 and 2018 we repeated the annual sampling we have conducted since 2013, evaluating all 11 of the $100M^2$ plots. We identified 199 taxa in these plots (and another 94 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 (e.g., Red Maple, Crabapple) and invasive species (e.g., Buckthorn).

The plant community in the Tamarack Bog is holding steady in the higher quality areas (Core and Edge), and is improving 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 9). Scores in the Enhancement areas initially rose, but have more recently declined, reflecting our subjective impressions of major changes in vegetation structure as the habitat adjusts to changes in the hydrology. We are monitoring these areas carefully for signs of improvement that we anticipate will be coming in the next few years. ANOVA confirms that the different areas respond differently (significant interaction: $F_{10, 48}$= 2.45, P <0.02), and that that habitat areas (Core/ Edge/ Enhancement) differ ($F_{2, 48}$= 130, P<0.001). Differences among years were not significant ($F_{5, 48}$= 2.08, P=0.08).

FQAI scores are currently high and show positive trends in all areas (Figure 10). 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, but shows a mild decline in recent years. Again, we are monitoring this carefully with the hope that the recent declines reflect the disturbance of a recently raised water level. ANOVA confirms that the differences among areas ($F_{2,48}$= 28, P<0.0001), and among years ($F_{5, 48}$= 13.8 P<0.005) are significant, while the interaction is not significant ($F_{10, 48}$ = 5.0, P>0.06).

Figure 9. VIBI and FQAI Scores

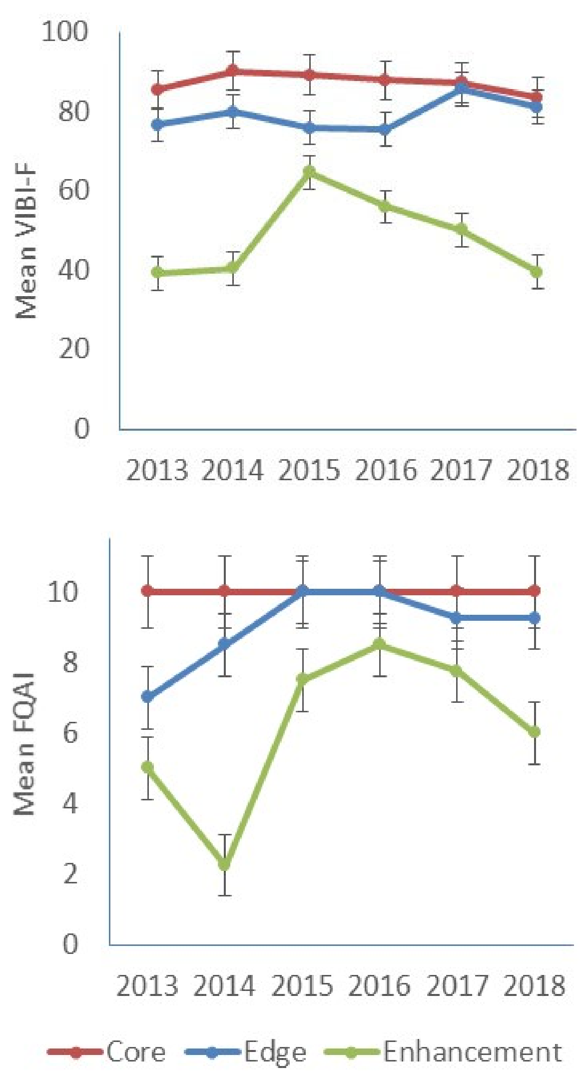

Table 1. Dominant plants (those with >5% mean cover) from VIBI plots in each wetland area during 2018. Values for proportion of cover represent mean absolute proportion cover for each species).

Core (81 taxa in 3 plots)	Prop. Cover	C of C	Wetland Indicator Status
Moss sp.	0.52	--	--
Decodon verticillatus	0.24	6	OBL
Alnus incana	0.21	6	FACW+
Rhamnus frangula	0.16	*	FAC
Larix laricina	0.14	9	FACW
Rosa palustris	0.14	5	OBL
Osmunda cinnamomea	0.11	6	FACW
Toxicodendron vernix	0.11	7	OBL
Rubus hispidus	0.07	5	FACW
Ilex verticillata	0.05	6	FACW+
Edge (100 taxa in 4 plots)			
Pyrus sp.	0.28	3	[UPL]
Symplocarpus foetidus	0.25	7	OBL
Pilea pumila	0.19	2	FACW
Carex lacustris	0.17	5	OBL
Fraxinus pennsylvanica	0.11	3	FACW
Osmunda cinnamomea	0.10	6	FACW
Rubus hispidus	0.10	5	FACW
Ilex verticillata	0.10	6	FACW+
Rhamnus frangula	0.08	*	FAC
Moss sp.	0.07	--	--
Rosa multiflora	0.06	*	FACU
Leersia oryzoides	0.06	1	OBL
Carex bromoides	0.05	7	FACW
Enhancement (106 taxa in 4 plots)			
Pilea pumila	0.31	2	FACW
Acer rubrum	0.21	2	FAC
Impatiens capensis	0.21	2	FACW
Carex lacustris	0.20	5	OBL
Polygonum virginianum	0.17	3	FAC
Leersia oryzoides	0.14	1	OBL
Carya cordiformis	0.10	5	FACU+
Acer saccharum	0.09	5	FACU-
Bidens cernua	0.09	3	OBL
Juglans nigra	0.09	5	FACU
Fraxinus pennsylvanica	0.07	3	FACW
Pyrus coronaria	0.06	3	[UPL]
Glyceria striata	0.05	2	OBL

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.), an upland species, are the most abundant species here (and are being targeted in invasive control efforts).

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 statuses (Table 2). Furthermore, species turnover in the Enhancement area has been much greater than that for the other areas: in 2018, only 2 of the 10 species with most cover in the Edge and Core areas differed from 2016's top 10 list. In contrast, for the Enhancement areas, 7 of the 10 species differed between 2016 and 2018. These responses indicate that raising the water levels at the Agridrain is driving vegetational change in these marginal areas, and should both expand and improve the wetland areas.

Indicator Status	2013	2018
OBL	0	2
FACW	4	2
FAC	1	2
FACU	4	3
UPL	1	0

Table 2. *Wetland Indicator status summary for the 10 species with most vegetative cover in the **Enhancement** area before restoration and in 2018.*

As a result, in this transitional period, species more tolerant of disturbance are thriving. We are hopeful that after a period of adjustment, the species composition in the Enhancement areas will continue to become even more wetland tolerant and develop a higher mean C of C.

Cover for the major invasive and problem species has strongly decreased over the last 6 years (Figure 10). Most of this decline is in Crabapples and Red Maple, 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 and Multiflora Rose are maintaining near the levels of 2016, with no dramatic increases or decreases.

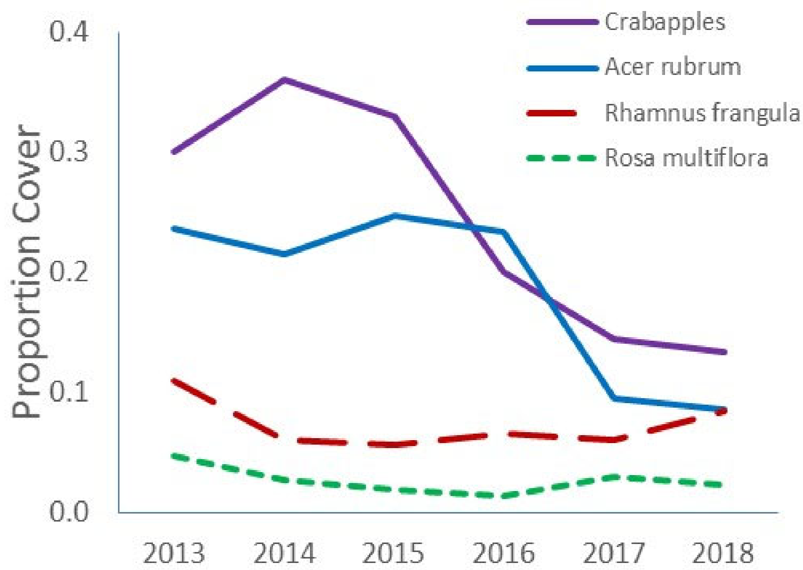

Figure 10. *Trajectories for prominent invasive and problematic species over time. N=11 plots each year*

Other invasives (e.g., *Phragmites* and Reed Canary Grass) are present, but are not common or increasing. In particular, 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 stem cover in the VIBI Modules was on average well above the target of 400 stems/acre (988 stems/Ha), but varied strongly over space and has changed over time (Figure 11; "unwanted" in this context includes invasive woody species, along with species not desirable in this habitat such as *Pyrus* sp., *Acer rubrum*, and *Prunus serotina*). In 2018 an unplanned change in scoring of 'clumps' for species like *Rosa palustris* and *Rosa multiflora* caused a dip in woody stem counts, but our experience (and data on % cover) indicate that this did not reflect an actual or worrying decrease. In future years we will return to our original scoring method for woody stems. Overall, the trajectory of woody plants in all areas is encouraging, with natives tending to hold steady or increase, and invasives decreasing.

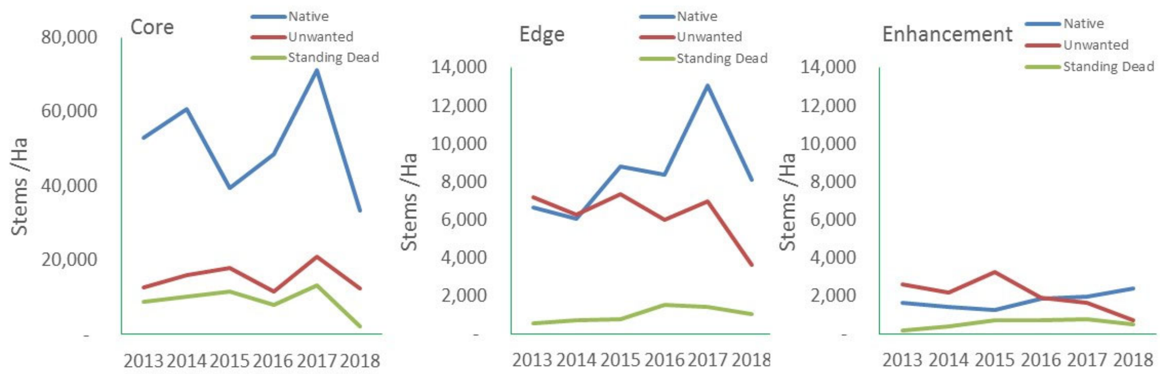

Figure 11. *Woody Stems for Native, Unwanted, and Standing Dead over time. N= 11 plots each year. Note different vertical axis scale for Core.*

In the Core bog the total stem count has maintained well over 30,000 stems/ha, with native species accounting for a clear majority of that total. Among the native species, *Rosa palustris*, *Alnus incana*, *Vaccinium corymbosum*, and *Ilex verticillata* together accounted for another ~54% of woody stems. *Rhamnus frangula* was the most abundant unwanted species, accounting for 19% of all woody stems in this area. There are no strong temporal trends in the Core.

Total stem density in the Wetland Edge areas was well above the target level but well below the values for the Core Bog (~12,000 vs. ~40,000 on average across years; note the larger vertical axis for the Core Bog than for the other two panels). In this habitat the abundance of native woody stems has trended upward, and that for unwanted species has started to decline (presumably reflecting management efforts and rapid decay of dead *R. multiflora* stems). Here the native *Ilex verticillata* made up about 24% of all stems, while the unwanted *Pyrus* sp. (crabapples) accounted for over 13% of total. Stems of both native and unwanted species were slightly declining on the edge, and standing dead was mildly increasing.

In the Enhancement areas the total stem density is averaging well over the target of . As in the Edge habitat the trends are good, with natives tending to increase, and unwanteds tending to decrease. *Fraxinus pennsylvanicus* makes up 51% of woody stems in this area, and the most abundant invasive is *Pyrus* sp. (12%).

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 six 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.)

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
Average	**32.96**	**9.53**	**5.91**	**70.20**	**45.06**	**27.26**	**20.23**	**41.83**
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
Average	**72.56**	**10.93**	**3.32**	**38.87**	**38.52**	**55.15**	**59.87**	**40.69**
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
Average	**69.09**	**9.64**	**2.32**	**44.39**	**44.02**	**58.34**	**66.38**	**48.99**

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
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
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
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
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
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
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
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

Plant Community Delineation

In 2016, we scored and delineated the different plant communities in the restoration area. We did not update that information in 2017-18, but plan to do so in 2020, to document possible changes in response to raised water levels.

Sphagnum and Moss surveys

Sphagnum plots. To evaluate coverage and potential expansion of *Sphagnum* moss, in Spring 2014 we established 52 permanent 2x2m quadrats (Miller 2016). 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*.

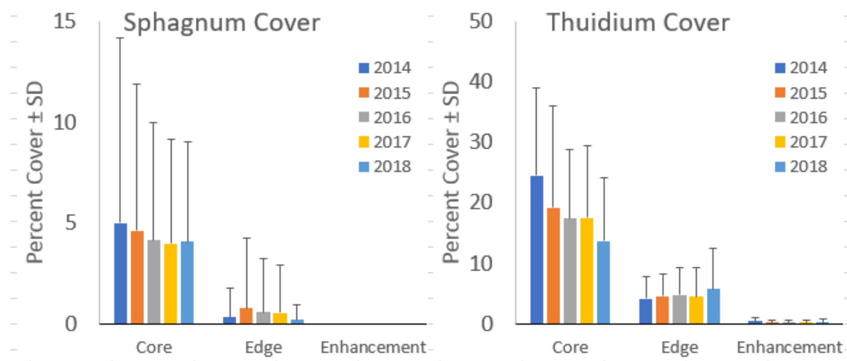

Figure 12. Sphagnum Plot coverage for two moss groups. Note difference in vertical axis

Sphagnum was not common overall, accounting for only 5% coverage in the Core areas, and almost none elsewhere. As of 2018, 12 of the 52 quadrats had any *Sphagnum* (the same as in 2016, and 1 more than at the start of monitoring, in 2014); these included 11 of 12 Core quadrats, and 1 of 8 Transect quadrats (Figure 12). *Thuidium* was much more abundant overall. Leaf litter differed dramatically among areas. Core bog areas had less than 3% leaf litter cover, while other areas have over 70% litter coverage. These values have not changed much over the 5 years of study.

In our 5 years of moss monitoring there are two notable trends. First, in Core areas there has been a slight temporal decline in both *Sphagnum* and *Thuidium*. This is mostly the result of reduced cover within plots, since the number of occupied plots is holding constant over time. Second, in Edge areas there is a slight tendency for an increase in cover over time. The causes and implications of these countervailing trends are not yet clear.

Sphagnum extent survey. 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 2017 and 2018 we found no evidence of a major outward expansion (although at 2 of 16 points we did see new sphagnum about 2m more towards the exterior).

Logs as moss habitat - Woody debris can be important for *Sphagnum* and other moss establishment (e.g. Fenton et al. 2007). Past felling of invasive trees left a lot of loose woody debris in the restoration, and we felt this presented an opportunity for a trial to investigate the influence of logs in wetter areas. With permission from the Army Corps of Engineers, in March 2016 we used some of this debris to create six small log jams along the abandoned ditch near the southeastern edge of the Core Bog to evaluate methods to establish *Sphagnum* and other mosses. Some moss has established here as of November 2018, and there is some indication that muck loss is reduced and that water flow in the old ditch is reduced during low flow periods. However, spring floods occasionally dislodge some of the logs, despite our attempts at pinning them in place with sticks and stakes. We are continuing to work to stabilize these.

Sphagnum growth in controlled conditions. In 2016, MS Tony Miller completed an MS Thesis at the University of Akron based in part on the *Sphagnum* surveys above, and in part on studies to evaluate whether *Sphagnum palustre* shows local adaptation to individual peatlands (Miller 2016). In that study two greenhouse experiments revealed that *Sphagnum* from three different source populations (including the tamarack bog) differed in growth, but provided no evidence of local adaptation to individual peatlands, suggesting that any *Sphagnum* introductions might benefit from using source material from a site with especially vigorous growth (Mentor Marsh, in this study). That MS thesis has now been published in the Ohio Journal of Science (Miller and Mitchell 2018).

Tamarack monitoring

Adult Tamaracks and natural regeneration. 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 remeasured them: Mean DBH for the 8 trees increased by 6mm. In 2018 we noted two trees with problems. One of the smaller trees appears to be dead, from unknown causes. Another now has several woodpecker holes in it, 2-15' above the ground. This may reflect ill health for that tree, so that the woodpeckers are seeking woodboring insects. We could not see any obvious signs of infestation or illness other than the excavations. We have not noted any new tamarack recruitment since 2016, when we noted one seedling that disappeared after a few weeks. All living trees continued to produce cones and seeds in 2017-18.

Tamarack Transplants I. In 2016 we set up a trial tamarack transplant study to evaluate methods for assisting regeneration. In June 2016 we planted 48 tamarack seedlings (purchased from Sheffield Seeds, NY) in the bog; 16 in each of the three regions of the restoration (Core, Edge, Enhancement). Since then we have revisited these stations and recorded survival, herbivory, and height. The seedlings were not caged or screened.

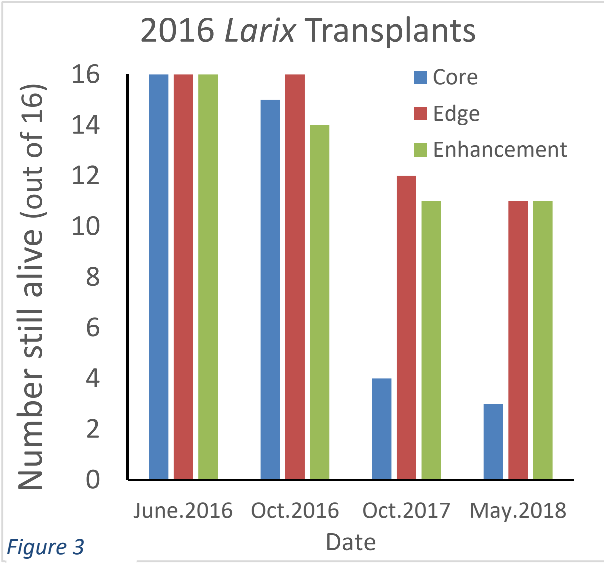

Figure 3

As of May 2018, 25 of the 48 transplants were alive (52.5%; Figure 13), and they had on average grown substantially (Figure 14). However, those planted in the Core area have not survived or grown as well as those in the Edge and (especially) the Enhancement areas. Our impression was that the problems in the Core reflect shadier conditions and unconsolidated substrate (difficult for planting and root establishment) in the Core.

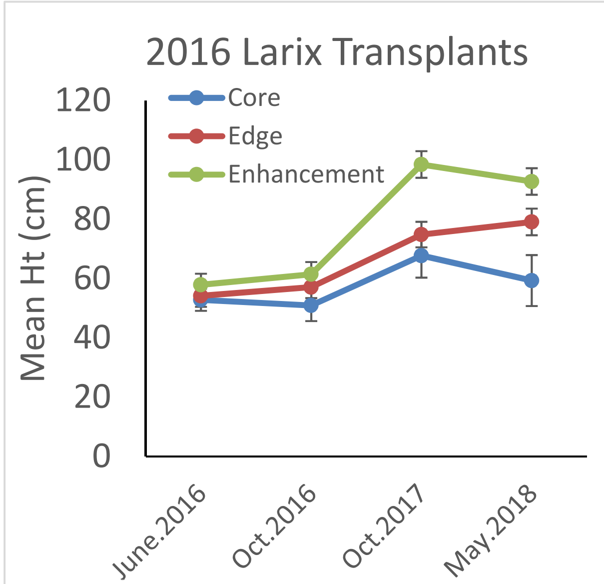

Figure 14

Many of the deaths for our 2016 transplants seemed to result from herbivory by deer. 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 it can be.

<u>Tamarack Transplants II.</u> In 2017 an Honors student at the University of Akron (Nick Lanz) began a second tamarack planting trial. 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.

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 areas (no overhanging herbs or shrubs), vs. closed areas (notable overhanging herbs or shrubs). Furthermore, in each of these plantings, 2 of the 9 transplants were enclosed in translucent plastic tubes to prevent herbivory. This study is ongoing, but as of May 2018 the results are as follows. Overall survival was 58.8%, with no differences in survival between open and closed habitats (χ^2 =1.3, p>0.25). Transplants in the open showed a non-significant tendency to be taller (86.0± 4.7) than those in closed areas (71±5.5cm; $F_{1,65}$ = 3.9, P>0.05). There has not been any herbivory on any seedlings from this study.

In the second design our student tested a different method for preventing herbivory - a 1m tall chicken-wire fence. He constructed 4 such fences (1.5×1.5m) in the Enhancement area, and

Table 5. *Heights of tamarack seedlings in 2018.*

Treatment	Mean ± SE Height	Alive/Total
Fenced	73.4 ± 5.04	20/20
Unfenced	67.2 ± 3.19	20/20

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. 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.

Plot Photos Over Time.

In 2014 we established repeat photography stations at each of the 11 VIBI plots. Those photos are included in Appendix E. We have also established photo sites at the transect endpoints. The repeat photos are presented in Appendix E. Those photos document a stable community in the Core bog (Plots 3, 5, 8), and increased herbaceous cover in Enhancement plots (especially plots 1, 4, and 7).

In April 2017 we installed four citizen science repeat photo stations along the boardwalk and have received nearly two dozen photos from the public by December 2018. We also use those stations for our own photos and have recorded 72 more images of those same sites ourselves. Because of the short time they have been in place we cannot yet draw any conclusions from those photos.

5. Invasive management

Through 2017, Davey Tree was visiting twice a year to spray herbicide on invasive herbs and shrubs. In 2015, they began girdling red maples and crabapples, primarily on the east side of the restoration area (see Appendix F). Although the initial efforts did not effectively kill the maples, modified techniques and renewed effort in 207 and 2018 have been more successful.

A communication from Thomas Babb of EPA (based on a summer 2017 visit) suggested that more effort on invasive control may be necessary. This is expected, since the wetland area is expanding (a sign of successful restoration progress!), and weeds are often the first colonizers of new wetland areas. Suppressing those invaders early on with aggressive control can prevent the invasives from dominating. Invasive control efforts have therefore been increased to three times/year. It is too early yet to precisely evaluate the effects of these increased efforts, but our impressions are that it is effective.

In 2018 we first detected a new invasive plant – Butterweed (*Packera glabella*), on the west margin of the restoration area. We have not detected it elsewhere at the Bath Nature Preserve. We counted 40 flowering stems in June 2018 and pulled them all before they could set seed. We will be carefully monitoring and protecting that area.

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

6. 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. And as mentioned above, 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.

7. 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 are working up a proposal for new target goals that accounts for these developments.

8. 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 E: Plot Photos

– see attachments

Appendix F: Invasive control summaries

– see attachments

9. Publications to date resulting from this project

(PDFs available online, or hardcopies available on request)

- 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, T. 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

10. 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.

Miller, T. 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.

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.

Fenton, N. J., C. Beland, S. De Blois, and Y. Bergeron. (2007). *Sphagnum* establishment and expansion in black spruce (*Picea mariana*) boreal forests. Canadian Journal of Botany 85:43-50.