University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2021

Analysis of a Recently Restored Appalachian Wetland

Emma Radulovic
Environmental Studies- Ecology and Biology
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Jeffrey Wilcox

Abstract

Riverbend Bog is a wetland in Henderson County, NC, that hosts a federally endangered, rare population of mountain sweet pitcher plants (*Sarracenia rubra ssp. jonesii)*. The Nature Conservancy recently implemented a restoration project to protect the pitcher plants from stormwater runoff that contains nutrients and invasive plant seeds. Stormflow and nutrient data, such as phosphorus, nitrate, and ammonium were collected and analyzed in this study to determine the relative success of the project. Sampling began in early Fall 2019 prior to completion of the restoration and continued through Fall 2020. The most significant findings were observed in early 2020, when stormflow was sampled from the farm across the street from the wetland. The retention cells filled with stormwater and re-routed runoff through the site without impacting the pitcher plants. Although further testing is needed as the retention cells mature, the preliminary results of this study suggest the restoration will help maintain the pitcher plant population by reducing risk from nutrient pollution or threats from invasive plants.

1. Introduction

Wetland areas are multifunctional and provide several services that support healthy ecosystems, including nutrient filtration, flood mitigation, shoreline protection, carbon sequestration, and biodiversity.[1] The complex characteristics that different wetlands possess allow for unique plants and animals to flourish. Depending on the type of wetland, different plants and animals can fill niches according to characteristics such as water depth, shade, nutrient conditions, and occurrence of other competing species. The basic traits of a bog include acidic, oxygen- and nutrient-poor soils, which makes it difficult for most plants to flourish.[2] Pitcher plants are carnivorous and have adapted to these conditions by developing various ways to trap and consume prey.[3] They can survive in nutrient-poor soils by sourcing necessary nutrients such as nitrogen and phosphorus from the insects they digest.[4] Because pitcher plants only have an ecological advantage in nutrient-poor conditions, they are extremely sensitive to alterations in nutrient availability.[5]

Riverbend Bog (Henderson County, NC) hosts a rare population of federally endangered mountain sweet pitcher plants (*Sarracenia rubra ssp. jonesii)* (Figure 1). These pitcher plants are exposed to runoff from a private farm and other properties further up the road. The runoff contains high concentrations of nutrients such as phosphorus and nitrate, which negatively impacts the population growth.[6] Seeds of invasive plants, potentially identified as Japanese Stiltgrass, (*Microstegium vimineum*), that have invaded the bog and are beginning to outcompete some native plants.[7] The pitcher plants face alterations in soil and moisture conditions, as a greater abundance of nutrients has allowed for woody plants (trees) to become established and increased evapotranspiration. Because of the threats facing this population of pitcher plants, the Nature Conservancy (TNC) received a wetland restoration grant to address the nutrient-rich stormwater runoff.

Figure 1 Image of Sarracenia rubra ssp. Jonesii.

TNC's primary goals of the restoration project were to reduce runoff into the site and promote expansion of the wetland habitat. To do this, three retention cells were constructed upgradient of the bog to retain stormwater runoff during extreme flooding events. Native plant species such as rushes, sedges, and other herbaceous plants were planted around the holding cells to absorb and filter out excessive nutrients as the water infiltrates into the ground. Large tree stumps were put in the cells to help promote aquatic life and habitat (Figure 2).

Based on the limited holding volume of three retention cells and the likelihood of overflow during the largest storm events, engineers installed a French drain along the edge of the site near the runoff source (referred to as the "Farm Drain"). While the French drain may help relieve flooding, it may also allow the nutrient-rich runoff to bypass the retention cells and enter the bog directly through an old sediment pond (referred to as the "Overflow Pond"). The goal of this study was to collect and analyze water samples from different locations throughout the site to determine the distribution of nutrients (phosphorus, nitrate, and ammonium) and evaluate the success of the restoration project to reduce stormwater and nutrient loads inside the bog and an eventual expansion of the pitcher plant population.

Figure 2 Pictures of Cell 1 post-construction Oct 2019, Mar 2020, and Oct 2020, respectively.

2. Methods

Sampling began in fall 2019 and continued until early spring 2020, until the COVID-19 pandemic limited further sampling until fall 2020. Site restoration was completed in November 2019, meaning there were three pre-completion sampling events, one at completion, and three after completion in spring and fall 2020. Most sampling events were during baseflow conditions, but one sampling event (2/6/2020) took place during peak stormflow (Figure 3).

Wells had been installed throughout the bog by previous research groups, and some were accessible for testing. Pre-construction samples collected from the inner bog areas were from wells 27S (shallow) and D (deep), 29S and D, and groundwater pond. Post-construction sampling was from the outer areas including the overflow pond, Farm drain, Cells 1, 2, 3 (Figure 4). Wells that were not sampled every trip were full of sediment due to unsaturated conditions or were physically inaccessible. Surface-water stream or pond samples were collected directly, while groundwater samples were pumped from monitoring wells using a peristaltic pump. An Oakton PC 450 meter was used to measure temperature, conductivity, and pH in the field.

The samples were taken back to the lab and analyzed for nitrate, phosphorus, and ammonia using a Hach DR 900 Colorimeter. Testing for nitrate was done according to the Nitrate MR method 8171, phosphorus according to Phosphorus method 8040, and ammonium according to Nitrogen, Ammonia method 8155[8]. Phosphorus was tested first because those samples could not be preserved for more than 48 hours after collection. If nitrate and or ammonium could not be tested the same day as collection, they were preserved, using sulfuric acid, and then tested within 28 days.

Figure 3 Images captured by a time-lapse camera showing the water level before the large rainstorm and during.

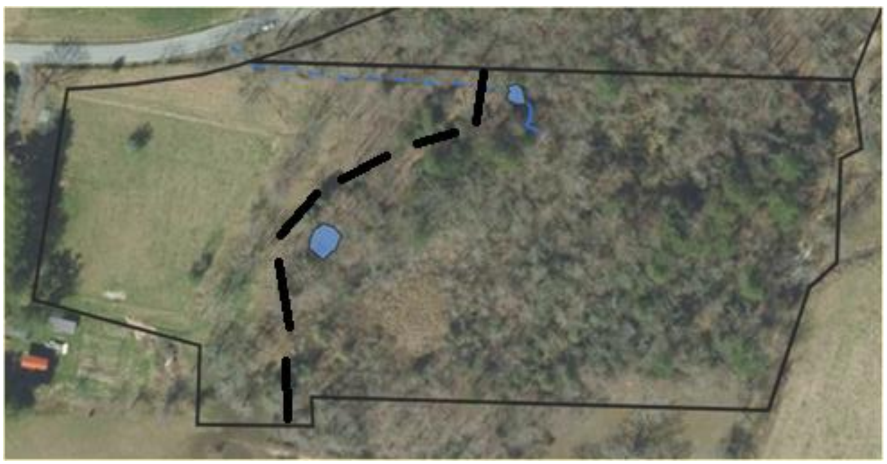

Figure 4 Map of the outer bog area (left of the black dotted line) where the retention cells were constructed, and the inner bog area (right of the dotted line) containing the pitcher plants. The larger blue circle is the groundwater pond and smaller is the overflow pond for reference.

3. Results

Nutrient data collected from this pond showed pre-construction levels of phosphate and nitrate were 0.32±0.37 mg/L and 0.43±0.12 mg/L respectively (Table 1). Post-construction baseflow samples from 2/20/20 and 10/3/20 showed nutrient levels essentially unchanged. Phosphate was considerably higher during the stormflow event on 2/6/2020 (1.13 mg/L), though nitrate concentrations were not elevated (0.5 mg/L).

Pre-construction nitrate levels stayed below 0.5 mg/L throughout the site. When surface water began flowing through the Farm Drain (source of the drainage from the farm and road runoff into the wetland), nitrate levels were 2-3 times higher than previous samples. Post-construction levels of nitrate were higher than phosphorus and ranged from 2-5 mg/L. Samples collected from the holding cells ranged from 0.1 to 3.6 mg/L of nitrate with an average of 1.3 mg/L between all 3 cells. The highest phosphate levels post-construction was measured in the farm drain (2 mg/L) and Cell 3 (which was too high for the Hach kit to read) on 2/20/2020. Cell 3 conductivity was relatively low (48.1µS/cm) compared to Cell 1 (102.7µS/cm) and 2 (91.2µS/cm) which both had significantly lower phosphorus levels (0.34 mg/L and 0.05mg/L).

Conductivity readings showed the wells in the bog and near the pitcher plants consistently ranged from 20-40 µS/cm while the overflow pond, farm drain, and holding cells were often 50- 100 µS/cm. Conductivity levels in the overflow pond decreased over time and eventually were near the levels found in the inner bog (Table1).

Indications of a new stormflow path was observed on 2/6/2020. The large rain event caused all three cells to fill to max capacity and overflow. Behind Cell 3 there appeared to be a new channel that carried the excess runoff around the edge of the bog, away from the pitcher plants and toward an adjacent property.

Table 1. Environmental Conditions and Nutrient Data. Samples taken on 9/17/19, 10/8/19, and 10/22/19 represent pre-construction baseflow.

Date	Sampled Area	Temp. (℃)	Conductivity (µS/cm)	pH	Phosphorus (mg/L)	Nitrate (mg/L)	Ammonium (mg/L)
9/17/19	27s	19.6	33.4	5.6	0	0.4	0.03
	27D	19	32.3	5.9	0.19	0.2	0.07
	29s	20.6	44.8	5.2	0.7	0	0.04
	29D	19.9	39.7	5.3	0.19	ND	0.03
	Overflow Pond	21.3	77	7.1	0.33	0.5	0.05
	Groundwater Pond	22.7	18.8	5.7	0.05	0	0.04
10/8/19	27s	18.3	27.99	5.7	0.43	0	0.11
	27D	18.3	34.18	6.3	0.03	0.5	0.08
	29s	18.9	25.38	5.6	0.09	0.1	0.12
	29D	19.5	35.48	6	0.38	0.5	0.09
	Overflow Pond	19.2	116.2	7.27	0.83	0.5	0.13
	Groundwater Pond	18.9	33.15	6.1	0.88	0.3	0.09
10/22/19	27s	16.3	29	5.7	1.68	0	0.08
	27D	16.4	32.3	6.1	0.09	0.4	0.8
	29s	17.7	26.4	5.4	0.43	0.2	0.09
	29D	19.7	36.5	5.9	ND	ND	ND
	Overflow Pond	16.7	74.5	6.9	0.08	0.3	0.16
	Groundwater Pond	18.1	39.9	5.8	0.1	0.2	0.1
	Farm Drain	22.6	75	6.6	0.45	1.1	0.09
11/21/19	27s	11.1	25	5.3	0.98	ND	0.21
	27D	12.1	29.3	6.1	1.19	ND	0.25
	29s	10.7	26	5.7	0.08	0.1	0.17
	29D	12	34.5	6.2	0.21	ND	0.25
	Overflow Pond	9.3	61.9	6.5	0.03	ND	0.39
	Groundwater Pond	13.6	31.6	6.6	0.14	0.2	0.2
2/6/2020	Cell 1	13.6	37.4	6.44	0.55	0.4	0.47
	Cell 2	12.8	53.4	6.69	1.19	3.3	0.5
	Cell 3	12.8	43.1	6.34	1.06	0.6	0.46
	Overflow Pond	12.2	43.8	6.22	1.13	0.5	0.44
	Farm Drain	13.1	72.8	6.28	1.24	2	0.37
2/20/2020	Cell 1	10.2	102.7	5.6	0.34	1.2	0.29
	Cell 2	8.8	91.2	6.2	0.05	0.5	0.14
	Cell 3	7	48.1	5.85	ATR	0.1	0.16
	Overflow Pond	5.3	34.5	5.94	0.06	0.3	0.2
	Farm Drain	7.2	59.9	5.82	2.1	2.2	0.14
10/3/2020	27D	14.4	30.82	6.6	0.11	0.2	0.16
	29s	15.4	23.18	5.6	0.41	0	0.19
	Overflow Pond	12	81.07	7.5	0.31	0.9	0.22
	Groundwater Pond	12.7	35.53	6.1	0	0	0.11
	Old Well 2	17.4	55.07	6.1	0.65	0.3	ATR
	Boundary D	15.2	19.61	5.5	0.03	0.2	0.15
	Cell 1	14.8	124.3	6.1	0.05	3.6	0.09
	Cell 2	14.4	69.14	5.8	0.01	0.9	0.13
	Farm Drain	19.3	125.1	5.5	0.57	5.1	0.09

Data collected from 11/21/19 was the first post-construction baseflow sample. Stormflow samples were gathered on 2/6/2020 during a large rainstorm and 2/20/2020 during a snow event. Fall baseflow conditions post-construction were collected 10/3/2020. *ND- No Detection **ATR- Above Testing Range.

4. Discussion

Pre-construction storm runoff flowed through an old sediment pond (overflow pond) directly to the area with pitcher plants. While the retention cells were designed to bypass that direct route to the pitcher plants, the French drain installed between the farm drain (source of storm runoff) and the overflow pond continued to flood the pond. Although the French drain was originally installed to help ease the pressure of Cell 1's limited holding capacity, it resulted in runoff diversion into the bog.

The nutrient levels for both phosphorus and nitrate were consistently higher from the farm drain and holding cells than the rest of the sampling sites in the bog. This confirms the farm drain as the source of polluted runoff and that the holding cells were able to contain most of the water that used to flow directly through the bog. Phosphorus adheres to soil as it moves underground due to its chemical properties and charge. Nitrate does not readily adsorb to soil particles and could still reach the pitcher plants via groundwater flow after infiltration. The planted native vegetation around the cells will be very important for filtering water after infiltration by nitrogen fixation and accumulation of excess nutrients to reduce nitrate concentrations in water infiltrating beneath the retention cells

Cell 3 phosphorus was elevated even though the conductivity was low. This could be because of the nutrients concentrating in the pool's surface, whereas normally they would have been distributed more evenly over a larger area. Cells 1 and 2 had high conductivity but low phosphorus levels; the phosphorus could have been diluted in the excess stormwater, due to their larger holding capacity in those cells and the fact they fill sooner compared to Cell 3.

The conductivity data shows a decrease over time post-construction in the overflow pond and central part of the wetland, suggesting that most storm runoff is being directed into the holding cells. The decreased nutrient and conductivity levels in the bog could also be due to the potential new route for runoff that was observed on the day of the large precipitation event in February. The overflow pond now connects to a channel running behind the holding cells towards the edge of the site and onto the next property. Nearly all the contaminated runoffs should bypass the area of pitcher plants and other native wetland species.

5. Conclusion

The source of nutrients is the farm drain; it directs runoff from the farm across the street into Riverbend Bog. Retention cell 1 is able to collect most of the runoff from the drain and overflow into the next cells, as designed, when capacity is reached. In the event where all cells are at maximum capacity, excess stormflow is routed away from the pitcher plants and off the site. To further reduce nutrients from the overflow pond reaching the pitcher plants, the French drain should be plugged and moved to the other side of cells 1 and 2 so excess flow can be directed out of the site and away from the pitcher plants. The retention cells have not yet reached maturity and should be monitored and tested further to ensure their capacity to hold and reroute stormflow. Based upon the preliminary results of this study, the restoration is reducing the risks imposed on the pitcher plant population by nutrient pollution and threats from invasive plants. In the future nutrient analysis of the inner bog should continue and mapping of pitcher plant population expansion will be useful to determine if the bog has become more suitable for the Mountain Sweet pitcher plant.

6. References

1. Beverly, C. R., Ausseil, A.-G. E., & Gerbeaux, P. (2013). Wetland Ecosystem Services. *Manaaki Whenua Press*, *1.14*, 192-202. http://www.mwpress.co.nz/__data/assets/pdf_file/0020/77042/1_14_Clarkson.pdf
2. Bog. (2020). National Geographic. https://www.nationalgeographic.org/encyclopedia/bog/#:~:text=Bog%20soils%20are%20oxygen%2D%20and,as%20heather%2C%20grow%20in%20histosol
3. Mellichamp, T. (2008). The Sarracenia Pitcher Plants and Bog Gardening. *Sibbaldia: The International Journal of Botanic Garden Horticulture.* 6, 77-99. DO: 10.24823/Sibbaldia.2008.36

4. USFWS. (2011). *Mountain Sweet Pitcher Plant Sarracenia rubra ssp. jonesii*. Fish and Wildlife Service. Retrieved 12 14, 2020, from https://www.fws.gov/asheville/pdfs/MtSweetPitcherPlant_factsheet.pdf.
5. Wilcox, J., Bradshaw Marino, E., Warwick, A., & Sutton, M. (June 15, 2020). Hydrology of a Southern Appalachian Hypocrene Spring-Fed Fen. *Environmental and Engineering Geoscience*; 26 (3): 359–366. doi: https://doi.org/10.2113/EEG-2308
6. Ellison, A.M., Gotelli, N.J., (2002). Nitrogen availability alters the expression of carnivory in the northern pitcher plant, Sarracenia purpurea. *Proceedings of the national Academy of Sciences.* 99, 4409–4412.
7. Boyer, T., & Carter, R. (2011). Community Analysis of Green Pitcher Plant (Sarracenia oreophila) Bogs in Alabama. *Castanea*, 76 (4), 364-376. Retrieved April 21, 2021, from http://www.jstor.org/stable/41416183
8. Hach Lab Instruments. (n.d). *Colorimeter: DR900 Colorimeter: Downloads.* Hach. https://www.hach.com/colorimeters/dr900-colorimeter/family-downloads?productCategoryId=35547203827