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Hydrochemistry of the Riverbend Bog

Matthew McGreal
Chemistry
The University of North Carolina at Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Jeff Wilcox

Abstract

Southern Appalachian Mountain Bogs are home to several endangered species, one of which is *Sarracenia rubra* subsp. *jonesii*, also known as the mountain sweet pitcher plant. These mountain bogs are delicate habitats that are greatly influenced by hydrology of the site. Riverbend, located in Henderson County, NC has undergone many management projects in order to maintain and restore the hydrology of the site. Hydrology and water quality are factors that have been identified to be beneficial in understanding the success of these environments. This study researches the presence of major ions in water samples around the bog in order to understand how the water quality affects the environment. The major ions studied are Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+} for cations and HCO_3^-, Cl^-, NO_3^-, SO_4^{2-} for anions. Current results compare data from three sample collections from November 2014, September 2015, and October 2015 that show patterns in the ions that classify water sources and also compare to other data collected from previous studies. It was found that the surface water had an impact on the areas surrounding the pitcher plants; the ionic fingerprint of the surface water source near the pitcher plants was varied by the presence of the runoff water source. Also, from this data it is concluded that during heavy flooding, fertilizers and runoff from the farmlands impact the water sources in the bog. Further research should be collected to increase data size of the sources in the Riverbend Bog to determine water quality effects on this environment from all the stressors present and ongoing restoration attempts.

1. Introduction

The Southern Appalachian Mountains are home to a variety of rare environments. Some of these rare environments are home to many rare and endangered plant species like the mountain sweet pitcher plant, making these ecosystems valuable for restoration. The Catskill Mountains in New York have wetlands similar to the ones found in the Southern Appalachian Mountains in North Carolina. Both bog types are part of the Appalachian Mountain Range and have very different climates but similar environmental features that classify them as bogs and that help these ecosystems thrive. One research group studied several Bogs in the Catskills and classified major features of the different bogs using geochemistry. The classifications of the wet lands were determined by vegetation, landscape position and water source. These three characteristics are all influenced by the water chemistry of the ecosystem, a main factor in maintaining these wetlands.[1]

Another study done by Thompson et al.[2] was performed in the Southeastern Kentucky Appalachian Mountains. This group also used water chemistry to observe wet lands characteristics. The study found that the Southeastern Appalachian bogs tend to have higher soil compositions of potassium, phosphate and ammonium as well as more acidic water sources. The three different sites this group studied had similar landscapes between one another and found that the hydrology of the areas all had a major influence on the ecosystem's success.[2]

1.1 Description of a Mountain Bog

Schafale and Weakley describe the Southern Appalachian Bog.[3] They describe many environments including a description of the Southern Appalachians Bog. These bogs have wet organic or mucky mineral soils and are very acidic. In these environments, the hydrology is normally fed by seepage or groundwater and the soils are constantly moist. Specific factors responsible for creating and maintaining these communities are not well known and studies are still needed. These environments are typically not well preserved, are known to deal with animals grazing and ruining the bogs as well as an overabundance of invasive shrubs and trees in the bogs habitable zones. Southern Appalachian bogs are normally associated with and often confused with a Swamp Forest-Bog Complex but there are distinguishable differences. Swamp Forest Bogs are normally closer to the streams while the Southern Appalachian Bog tends to be further away from streams. This is the case at the Riverbend research site; Gash Creek is located far north of the bog which helps classifies it as a Southern Appalachian bog. In addition, the Southern Appalachian Bogs are typically zoned or patched in a small area sometimes at the bottom of a basin or valley and are over run by dominating shrubs and trees at the interior.[3]

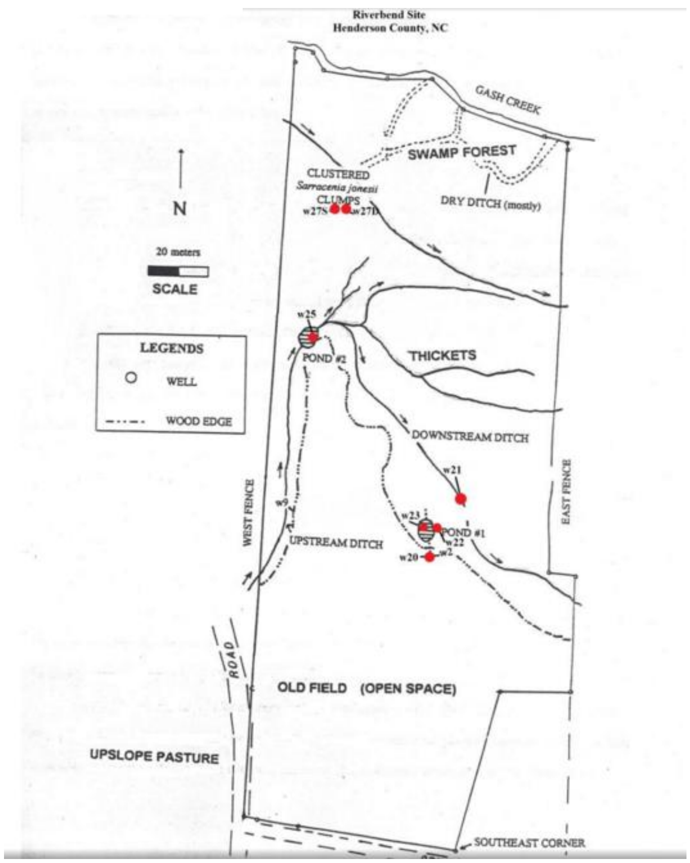


Figure 1. Location of the wells at Riverbend bog site Henderson County, NC. 2013. Adapted from The Nature Conservancy's Hydrologic Summary of Riverbend[4]. The red dots represent the wells from the sample site denoted with w with the sample name or number associated.

1.2 Site Description

Riverbend research site has all the qualities of a Southern Appalachian Big as previously stated by Schafale and Weakley.[3] In Figure 1, Riverbend is labeled showing the clustered pitcher plant site, Gash Creek to the North, the Farmland that impedes the Bog from the south labeled as old field and the large field that partakes in the flooding of the bog from a higher elevation to the southwest corner of the diagram and is labeled as upslope pasture. To the left of the upslope pasture is a small community and when it rains heavily, the rain is directed through the large field and floods a few feet deep across the main road into the upstream ditch. The flood path then passes through this bog in the upstream ditch into pond 2 then floods through to the pitcher plants.

The Nature Conservancy decided that reduced flooding into the bog will reduce stress as well as the manual removal of invasive species. Reducing flooding reduces stress by controlling the amount of pollutants and unnatural wastes that will enter the bog. Monitoring the *S. jonesii* in this site for any harmful impacts during the management is key because Riverbend supports one of only 10 known populations of these endangered species in the world.[5] Since the paper was written in 1995, one of the populations has been lost. In 2010, after many years of data collection, the nature conservancy gathered that increasing the size of the pond 2 would reduce the stress from flooding so the pond was dredged to a larger size.[4] New research after the dredging of pond 2 in 2010 is being conducted to see the effects of this pond on the environment. Due to the purpose of pond 2, it is called the overflow pond from here on.

Previous student research was conducted in this site by Scott Dinsmore, 2013.[6] He conducted research at the two ponds on the site. By geothermal imaging and rainfall patterns, he deduced that pond 1 was almost entirely fed by groundwater (GW). This was due to the water level consistency in wet and dry periods, the fact that the GW pond did not freeze during the winter, and the data collected from geothermal imaging. From here on, pond 1 will be called GW pond due to the information gathered by Dinsmore. The overflow pond, which was the pond dredged larger to reduce the flooding into the bog, was also found to be ground water fed but due to fluctuations to the water level before and after rainfall, concluded this pond was also heavily influenced by surface water/runoff.

1.3 Objective

Understanding the characteristics present in each bog environment by the water chemistry and identifying their successful features in each community is vital for the mountain bog ecosystem's success. The environment characteristic studied in this paper that can aid in successful restoration in a wetland is the hydrology of the environment. Some of the hydrological factors that influence a site are the groundwater source, surface water source, and runoff from nearby ecosystems. Another main factor found in wetland environments that plays a role in the success of restoration efforts is flood waters during heavy rainfall and the influence of the site topography.[7]

The goal of this research is to study the hydrology of the environment using water chemistry to understand and map the sources of water that influence the pitcher plants populations. To achieve this goal, "water fingerprinting" will be used to identify the sources of water in the bog and classify the composition and ions in each source. Another goal is to further increase knowledge of the Southern Appalachian Bog as well as confirm Dinsmore's data to help aid in Riverbend's site management decisions. To classify the compositions of ions in water samples, Ion Chromatography will used to test for major ions in the water.[8] Representations of the different ions present in each water sample will be analyzed by piper diagrams.[9] There are several other wildlife preserve agencies working with the Nature Conservancy in the Riverbend Bog that are also conducting studies in order to help preserve the pitcher plant environment in the manual removal of woody species at the site.

2. Methods

Sample collection one was collected November 20th, 2014, sample collection two was collected September 8th, 2015. The samples were collected from several sites around Riverbend for several surface and ground water samples using monitoring wells that were already on site. Each sample location was repeated in the same spot or as close as possible for each sample between each collection period. The sites are labeled in Figure 1.

2.1 Sample collection

All samples were collected in high-density polyethylene bottles and stored in a cooler during transportation to the laboratory then refrigerated until use. To collect surface water the bottles were labeled and then placed in the water. Groundwater samples were collected from the monitoring wells, shown in red on Figure 1[9].

2.2 Filtration and Preservation

All samples were filtered to remove sediments and solids by using a vacuum pump and 0.45 µm nylon filters. Each filtered sample was then separated into 3 aliquots. The cation aliquot was preserved with a small amount of concentrated nitric acid to stabilize any metals in solution and prevent them from sticking to the container walls; the other aliquots for anion analysis and alkalinity were left unpreserved[9].

2.3 Ion Analysis

Calibration curves were generated for common cations Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+} and for common anions Cl^-, NO_3^-, SO_4^{2-} from 0.4 ppm to 12 ppm. Samples were analyzed for the common ions listed with a Dionex LC120 ion chromatograph. The mobile phase for cations was methane sulfonic acid and sodium bicarbonate for anions. Due to the mobile phase of the anions containing bicarbonate, alkalinity titration to calculate the concentration of HCO_3^- ions needed to be done. Approximately 50 mL of each sample was titrated with 0.0118 M HCl for an alkalinity titration to calculate the bicarbonate in each sample. All ions, except NO_3^- and NH_4^+, were used for calculation of charge balances and generation of piper diagrams[9].

3. Results

Results up to date consist of three data sets of water samples collected at the bog. The first samples were in December of 2014, the second was in September of 2015 and the third in October 2015. The December samples were taken during a period of no snow on the ground with a high water table and wet ground. This differed from the sample collection period in September. During the second collection, the water table was very low and the bog was extremely dry. The overflow pond was completely dry with only ground water present, shown in Figure 2. It was difficult to take water samples during the second collection due to lack of surface water. However, all samples collected in the first set were replicated in the second, with one additional sample taken from well 2 during the second collection. Well 2 was a ground water sample taken from a well that was closest to the Staff Gauge sample, labeled w21 in Figure 1. The third sample collection in October 2015 was different conditions that both set one and set 2. The conditions in the bog were very wet with a high water table due to a recent occurrence of flooding in the bog. An additional sample location was taken during this set and it was called farm runoff. This sample was a surface collection sample from a drainage ditch that was water runoff from the neighboring farm. We found that during this flooded period, there was increase NO_3^-, assumed to be from fertilizers from the farm. The increased nitrate is why in Data Table 1 the charge balance for sample 3 has a negative value with more anions present than cations. Data Table 1 includes the charge balance of all 3 sets but also shows the concentrations of each ion in ppm of each sample collections. It is difficult to analyze the samples using the ppm concentrations due to the fact that the concentrations of each ion in the samples are not consistent. The ratios of different ions determine the fingerprint for the source, not the concentration of the ions. Piper diagrams use milliequivalents that factor in the molar mass of each ion to form ratios that compare multiple sites. Piper diagrams are created in Figure 3 to compare the ion ratios in the samples between the wet period in December to the dryer period in September to the flooded period in October.

Figure 2. This picture depicts sample collection two. The overflow pond is normally filled with runoff water, however the only water that is present is groundwater since this portion of the pond is lower than the water table.

Table 1. This data table compares the 3 samples from Riverbend per sample location in ppm. The charge balance of each sample in anion/cation percentage is also included. All samples are in the 10% margins except for the December Staff Gauge and September 27s samples. n/a data points were samples locations that were unable to be collected and BLOD are samples that were below the limit of detection.

Anions	Cl^-	**Cl^-**	**Cl^-**	NO_3^-	**NO_3^-**	**NO_3^-**	SO_4^{2-}	**SO_4^{2-}**	**SO_4^{2-}**	HCO_3^-	**HCO_3^-**	**HCO_3^-**	**Sample 1**	**Sample 2**	**Sample 3**
Overflow (25)	3.38	2.28	3.24	0.39	0.57	17.11	4.93	1.22	5.66	11.27	29.92	3.80	11.40	9.53	-8.26
GW Pond (23)	2.03	2.40	2.15	0.32	0.35	0.39	0.43	0.13	1.32	8.92	11.12	5.00	3.40	6.36	-9.26
Staff Gauge (21)	2.55	1.25	3.20	0.14	0.35	2.94	0.29	1.16	4.59	28.82	18.87	3.50	12.49	10.87	-13.80
Gash Creek	3.89	3.71	2.52	2.87	1.34	4.92	2.25	1.00	4.89	26.48	41.55	13.40	7.18	5.13	6.94
27s	2.97	1.19	2.00	0.33	0.35	0.59	0.37	0.13	2.60	0.29	7.61	BLOD	7.20	20.98	-21.84
27d	1.99	2.40	n/a	2.53	2.36	n/a	0.21	0.13	n/a	5.12	9.36	n/a	0.56	6.57	n/a
Well 2	n/a	4.02	n/a	n/a	0.68	n/a	n/a	0.13	n/a	n/a	10.10	n/a	n/a	4.72	n/a
Farm Runoff	n/a	n/a	1.95	n/a	n/a	14.48	n/a	n/a	9.47	n/a	n/a	4.10	n/a	n/a	-3.75

Cations	Na^+	**Na^+**	**Na^+**	NH_4^+	**NH_4^+**	**NH_4^+**	K^+	**K^+**	**K^+**	Mg^{2+}	**Mg^{2+}**	**Mg^{2+}**	Ca^{2+}	**Ca^{2+}**	**Ca^{2+}**
Overflow (25)	1.58	2.12	BLOD	0.00	5.04	BLOD	2.08	3.43	BLOD	1.96	1.23	2.52	4.12	3.06	5.14
GW Pond (23)	1.51	1.90	BLOD	0.49	0.69	BLOD	1.32	2.60	0.72	0.52	0.55	0.82	1.28	1.21	1.22
Staff Gauge (21)	1.70	4.54	BLOD	2.59	2.47	BLOD	3.01	2.41	0.05	1.76	0.26	1.22	5.42	0.96	2.37
Gash Creek	4.78	7.31	1.77	BLOD	BLOD	BLOD	2.14	2.45	2.12	1.87	1.86	1.86	6.39	7.70	5.17
27s	0.94	3.98	0.90	BLOD	BLOD	BLOD	1.21	1.37	BLOD	0.32	0.22	0.40	0.39	0.57	0.10
27d	2.09	3.47	n/a	BLOD	BLOD	n/a	1.69	2.24	n/a	0.17	0.35	n/a	0.78	1.23	n/a
Well 2	n/a	2.53	n/a	n/a	0.37	n/a	n/a	2.47	n/a	n/a	0.66	n/a	n/a	1.46	n/a
Farm Runoff	n/a	n/a	BLOD	n/a/	n/a	BLOD	n/a	n/a	BLOD	n/a	n/a	2.56	n/a	n/a	6.06

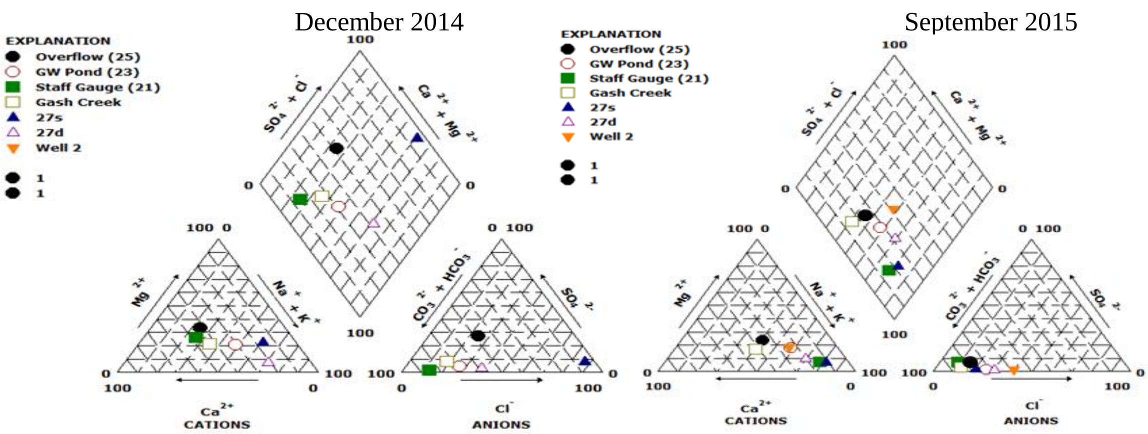
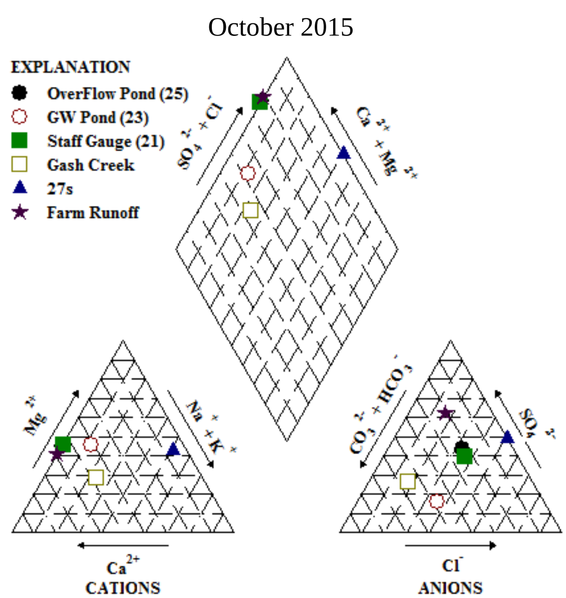


Figure 3. These piper diagrams compare the ratios of ions present between the 3 samples using milliequivalents (m_{eq}).



4. Discussion/Analysis

Upon analysis of the results, it can be found that the samples confirm the allegations put forth by Dinsmore's research in 2013. The data confirms that the GW pond is almost entirely groundwater fed and that the Overflow pond is slightly groundwater fed, but more heavily influenced by water runoff and surface water based on the ionic fingerprints created. A point that Dinsmore made in his research to ensure better land management of Riverbend was to investigate whether or not surface water was reaching the pitcher plant site. Investigation into this issue is important because the Nature Conservancy enlarged the overflow pond in attempt to contain the flooding when in fact, the flooding could potentially be an important water source for the pitcher plants, making it a factor of the species survival. One piece of evidence that supports the hypothesis that the flooding is important to the survival of the pitcher plants is a film taken by Wilcox. The film shows intense flooding in the bog that fills the entire overflow pond as well as the entire surface around the pond as a layer of the surface water.[10] The research performed in this study looked further into the flooding to deduce whether or not the flood waters traveled far enough into the site to feed the water source of the pitcher plants through ionic fingerprinting. The results of this experiment confirm the water source that feeds the pitcher plants does contain surface water.

In reference to Figure 3, when comparing the GW pond data between the three sample sets, one can see the ionic composition of the water stays relatively consistent between the wet and dry period. During flooding, the GW pond's plot was shifted up due to the increased runoff present in the pond, but it was still slightly lower than pure runoff from ground water influence. This shows that the pond is mostly groundwater fed and can be filled by runoff during heavy rain. Other samples that remain similar in composition between data collections are Gash Creek and 27d, which show that these also are more ground water fed. This is reasonable due to depth of the well at 27d, and the fact that Gash creek is below the water table and constantly flowing. In set 3, Gash creek was the same as the GW pond; it was slightly shifted lower from ground water influence but still shifted upward due to increased runoff presence. In the September 2015 sample set, all samples, some more than others, have their ionic ratios shift down towards the GW pond. When a sample shifts down, there are fewer ions in the sample, depicting a lack of surface water. Comparing the overflow pond and 27s, the pitcher plant site, when the bog was very dry, the overflow pond and 27s had no surface water present, resulting in the ionic ratios shifted down towards the GW pond. This implies that these sample sites are heavily runoff fed. When the bog was wet in December 2014, the samples had their own distinct ionic fingerprint shifting away from GW pond due to runoff as a major water source for the pond and plants. The sample that does not follow the trend between data sets is the staff gauge sample. The sample was neither more runoff fed nor groundwater fed showing that the sample has an ionic ratio that is a mixture of both the surface water source and the ground water source. This explains the shift towards the bottom of the September 2015 piper diagram for the samples. One finding of this study is that removing the flooding all together by increasing the size of the overflow pond can be harmful to the pitcher plants habitat due to the nature of the surface water source. The water that feeds the plants (27s) is not only groundwater fed, as we see in the 27d sample, but also fed with another source of water that changes the ionic fingerprint of their area. Due to the shift towards higher concentrations of chloride in 27s in both the wet sample 1 and the flooded period sample 3, it is assumed that some factor around 27s is increasing the chloride ions present. This could be from protective efforts taken by groups working to restore the environment. For example, if they spray herbicides to prevent overgrowth from unwanted woody species or growth that hinders the pitcher plants success. There currently is not a definitive answer to what caused this shift in chloride ions.

5. Conclusion

These results classify the ionic fingerprints of the ground water and surface water sources present in Riverbend. This helps direct future studies by sampling other locations in Riverbend to determine the influence of ground water and surface water on possible locations for more accurate habitable zones for pitcher plants to grow. After classifying these two sources that feed into the bog, a ratio of runoff to groundwater can be presented for every sample that was taken at the site. This allows researchers to figure out the ionic ratio present in each sample for the different water sources, as well as the intensity of the influence of each source on different sites around the bog. This is beneficial because the preference of the pitcher plants can be found, allowing growth to the more suitable locations for the plants, based on the condition of current populations in the bog.

These results also show that during periods of heavy rainfall, flooding of the bog occurs that that adds unwanted nitrates and fertilizers which are washed into the bog as shown in sample set 3. Increased nitrates causes issue to the pitcher plants because they are not competitive species and easily succumb to other species. These plants have adapted to thrive in nutrient poor locations to achieve their competitive edge. When these additional nutrients and fertilizers are washed into the bog by flooding, species that are invasive to the pitcher plants have better conditions to grow and overburden the pitcher plants.

This study showed that surface water influences the pitcher plants water source. In the future, the Nature Conservancy could attempt to increase the area of growth for the pitcher plants. In this case, it is highly suggested to find a location that is in range of the surface water flow due to the fact that the current pitcher plants are doing well in their current habitat. Replicating the current pitcher plant conditions is the key to improving the population size of these endangered species. The Nature conservancy should also look into reducing the flooding into the bog and prevent the increase of nitrates and fertilizers in the bog. The data shown has proven that there is influence from the two water sources, and using ionic fingerprinting is a viable method for evaluating this variable. One could improve the experiment by expanding the number of samples taken while also creating a more precise map around the site to increase the areas that could be possible habitable zones for pitcher plants.

6. Acknowledgements

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