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EFFECT OF SUBSURFACE GEOLOGY ON THE WATER QUALITY OF SPRINGS AT THE RAYSTOWN FIELD STATION

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ABSTRACT

Juniata College's Raystown Field Station resides on Raystown Lake in south central Pennsylvania and is underlain by two geological formations, the Scherr and the Foreknobs. The different compositions of these formations may affect spring water quality, which in turn may alter the water quality of Lake Raystown. I tested the hypothesis that there is a difference in the water quality between the springs of the Scherr and the Foreknobs formations. To accomplish this I analyzed three springs from each formation for temperature ($P \leq 0.05$), pH (P=0.693), conductivity (P=0.616), alkalinity (P=0.783), and turbidity ($p \leq 0.05$) and found no significant difference between the formations. I then tested the hypothesis that there is a difference between spring water quality and lake water quality. I found significant differences in temperature (P=0.002), pH (P=0.000), conductivity P=0.000), and turbidity (P=0.018), but not in alkalinity (P=0.352). This data is useful in characterizing the water quality at Juniata's Field Station, and allowing for characterization of stream water quality feeding into Raystown Lake. Such information can be useful in determining the health of Raystown Lake.

Keywords: alkalinity, conductivity, pH, sandstone, shale, Raystown Field Station, springs

INTRODUCTION

Raystown Field Station is underlain by the Scherr geologic formation, to the southeast is the Foreknobs formation, and lastly, beneath the Lake, is the Catskill formation (Fig 1). These formations were deposited during the upper Devonian. The Scherr formation is the oldest of the three and is composed of gray siltstone, shale, mudstone, and some sandstone, and can reach a thickness of 1,900 ft. The siltstone and sandstone are primarily olive gray to greenish gray, and the mudstone and shale are predominantly medium gray. The Foreknobs formation is about 1,500 to 1,600 ft thick and consists of conglomerate, sandstone, siltstone, mudstone, and shale. The Catskill is the oldest strata under examination. Three fourths of this formation is composed of shale and mudstone, with sandstone making up the remainder. Eighty to 95 percent of this formation is red in color. (Taylor et. al. 1982)

These differences in geologic composition may result in variations in the water quality between formations. (Mutti Pers. Comm.)Sandstone has a higher porosity than shale because of its larger grain size allowing for faster infiltration. However, it is highly possible for an equal infiltration rate to occur in the shale if water has previously carved a conduit through the rock increasing the infiltration capacity. The weatherable minerals in the subsurface geology and soil composition of carbonates have a tendency to neutralize acidity and produce alkaline waters. However, little to no carbonates have been identified in these three formations. (Taylor et. al.1982)

Geologic composition has the ability to influence temperature, pH, and alkalinity. The duration of water storage within the strata can determine the temperature of the ground water. If water is contained within the strata it will become the temperature of the strata, approximately 10°C, which is maintained year round. Contrary to this, surface water assumes the temperature of the environment and varies throughout the year. (Washburn Pers. Com.) The buffering capacity of geologic strata can influence water quality by increasing the pH. pH is defined as the concentration of H+ ions in water and is determined by –log[H+]. (Harris 1999) It is measured on a scale of 0 (very acidic) to 14 (very basic) with 7 as neutral: pure water at 25°C (Zagorski 1997). The acceptable level of pH in natural waters is between 6.5 and 9.0 (Horne et. al. 1994), although this varies among publications. Alkalinity is similar to pH, as it is measured in the same units, however is the capacity of natural water to react with H+ to reach pH 4.5. This is the second equivalent point in the titration of carbonate (CO_3^{-2}) with H+ and assists in determining the buffering capacity of the geologic strata.

Conductivity and turbidity are influenced by the productivity of the aquatic system. Conductivity is a measure of the total ions present in a body of water, which allow water to conduct an electrical current. (TPS internet) Conductible ions are more prevalent in stagnant bodies of water as compared to springs as it is dependent on the productivity of the water source. Turbidity is a measure of the dissolved substances suspended in the water, which determine the ability of light to penetrate further indicating the productivity of the aquatic system (Henley et. al. 2000).

As all of these factors are dependent on retention time in the strata, it has been suggested that stream analyses be conducted at base flow to ensure that the results are impacted by subsurface geology rather than surface runoff. (Thomas et. al. 1999)

I compared the Scherr and Foreknobs formations located at Raystown Field Station to determine if there was a difference in the chemical water quality (temp, pH, conductivity, alkalinity, and turbidity) emitted. I also compared this data to Raystown Lake, underlain by the Catskill formation to determine if there is a difference between lake water quality and spring water quality.

FIELD SITE

I conducted my study in Huntingdon County, Pennsylvania on the shores of Lake Raystown. The Scherr is located under the Field Station, the Foreknobs is found to the southeast on Army Corps of Engineers property leading to Nancy's Camp, and the majority of Raystown Lake is underlain by the Catskill formation (Fig 1). The Berks-Weikert soil association overlies these formations (Hockman-Wert 2001). This area currently has deciduous to mixed forests (Hockman-Wert 2001) with a significant riparian zone and was previously utilized for agricultural purposes until 1972 when Raystown Dam was constructed (Grove Pers. Comm.). I analyzed 3 streams in each geologic formation as well as lake water at the inlet of Juniata Bay (J-Bay). I conducted this study from mid February to mid March 2001.

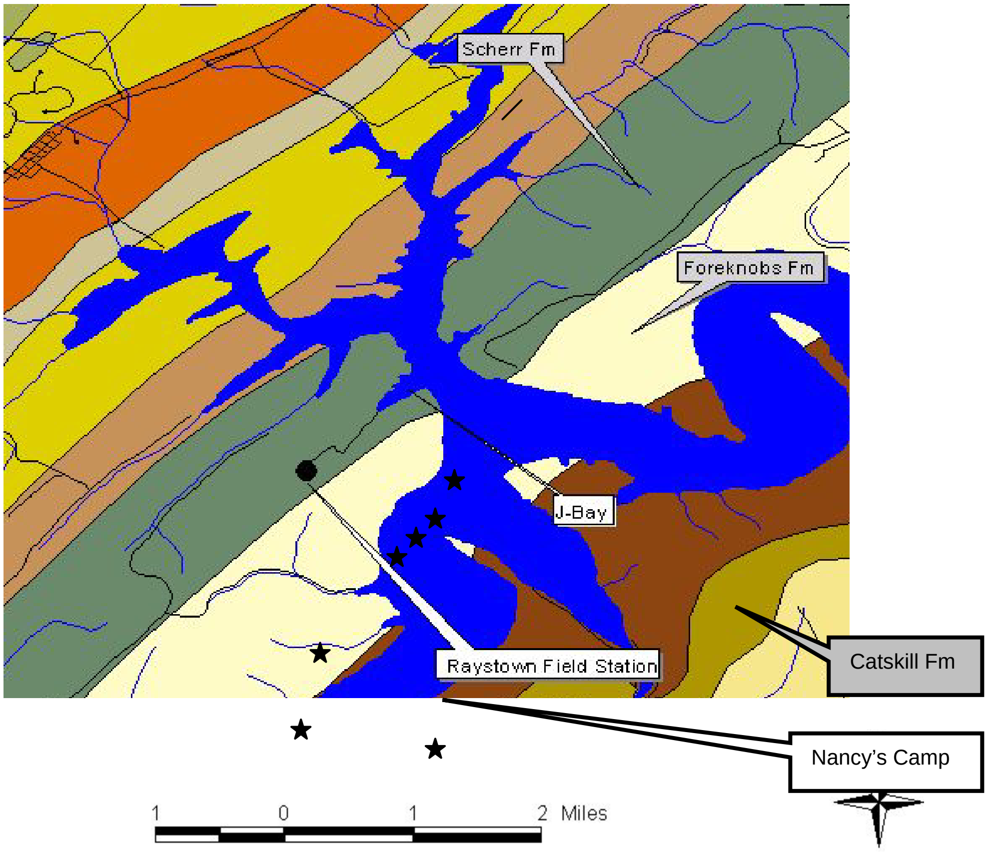

Figure 1. Study sites on Raystown Lake in Central Pennsylvania - 3 sites were located in each of the Scherr and the Foreknobs formations, with an addition site at J-Bay.

METHODS

Using a geologic map I located 3 suitable streams in each of the Scherr and Foreknobs formations that would not run dry in the event of decreased rainfall. I visited these 6 springs on 5 different days. I conducted tests for temperature, pH, conductivity, alkalinity, and turbidity. I collected 3 sets of data from each stream for each day in the field, and repeated the chemical sampling with 10 replicates for each test in J-Bay on an additional day. I operated a pH meter to measure temperature and pH, a conductivity meter for conductivity, and a Hack Kit for alkalinity and turbidity.

I used a paired design to compare the 2 formations using the sample days as my pairing variable. Each day I calculated the differences between the spring averages for temperature, pH, conductivity, alkalinity, and turbidity. I analyzed the data for normality with an Anderson-Darling test, and for heterogeneity of variances using a Levene test. I utilized a non-parametric test, 1-sample Wilcoxon, for temperature and a 1-sample t-test for pH, conductivity, and alkalinity. I analyzed turbidity with a Welches t-test. To compare Raystown Lake to the different geologic formations I used a Kruskal-Wallis Test for all analyses. I maintained an alpha level of .05 and considered results below this to be significant.

RESULTS

A total of 100 tests were run for each parameter (springs and lake combined). I compared the

Table 1. Averages and Standard Deviations of temperature, pH, alkalinity, turbidity, and conductivity for all locations.

	Temp	pH	Alkalinity	Turbidity	Conductivity
Lake	4.0 ± 0.04	6.9 ± 0.13	3.8 ± .044	3.0 ± 2.36	238.3 ± 4.42
Scherr	5.9 ± 1.49	5.4 ± 0.64	6.0 ± 3.61	12.7 ± 13.30	60.9 ± 14.59
Foreknobs	5.9 ± 1.80	5.2 ± 0.23	5.1 ± 3.02	24.7 ± 51.90	54.9 ± 12.93

Scherr and Foreknobs formations and found no significant difference in temperature (df=1, $P \leq 0.05$), pH (T=0.41, df=1, P=0.693), conductivity (T= -0.52, df=1, P= 0.616), alkalinity (T= -0.28, df=1, P=0.783), or turbidity (df=1, $p \leq 0.05$). However, when I compared these to J-Bay, a highly significant difference was present for temperature (H=12.30, df=2, P=0.002), pH (H=22.01, df=2, P=0.000), conductivity (H=21.99, df=2, P=0.000), and turbidity (H=8.03, df=2, P=0.018). There was no significant difference in the alkalinity levels (H=2.09, df=2, P=0.352).

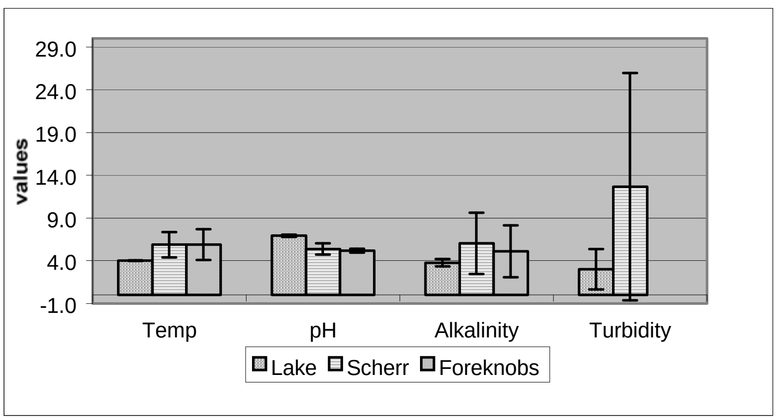

Figure 2. Average temperature, pH, alkalinity, and turbidity at all three locations. Values for Foreknobs turbidity are: 24.7 ± 51.90.

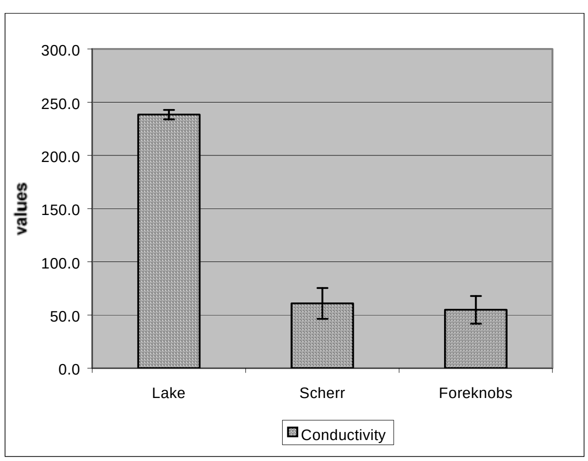

Figure 3: Averages and standard deviations of conductivity at all three locations.

DISCUSSION

The temperatures were most likely higher in the springs than in Raystown Lake due to the impact of winter freeze on lake temperature. In February/March, when I conducted my research, the lake water was still recovering from the winter freeze. Additionally, if the geologic strata had impacted the spring water it would have been maintained at approximately 10°C (Washburn Pers. Comm.), therefore the spring water was predominantly the result of runoff, as it was significantly colder and not impacted by the subsurface geology for any length of time. Repeat testing in the summer would most likely reverse this result as the lake water would be warmer and the subsurface geology would impact the spring water during this low-flow season.

The pH of J-Bay was near neutral and higher than that of the streams. A possible explanation is the greater CO_2 in the lake water due to greater photosynthetic effects. Both of the averages are within the acceptable levels of 6.5 and 9.0 (Horne et. al. 1994).

Conductivity of J-Bay was significantly greater than the springs possibly explained by the increased productivity in Raystown Lake. The descriptions of lakes provided by Horne (1994) indicate that this area of Raystown Lake is mesotrophic. (Degagne Pers. Comm) The ion content at this trophic level is greater than a spring as little productivity is present in the springs based on its size limitation to aquatic life, whereas lakes contain abundant high-order life. These larger specimens increase the impact of defecation and decomposition increasing conductivity. (Horne 1994)

Turbidity was significantly lower in the lake, as it has the ability to allow sediments to settle to the hypolimnion leaving a greater visibility in the epilimnion. Light penetration is typically 2m to 8m in a mesotrophic lake. (Horne 1994) Turbidity testing in the lake was only done within the first meter attributable to low turbidity numbers; additional depths may increase the turbidity. Springs however do not allow for sediment to settle to the spring bottom, but rather the current carries sediment downstream. This results in increased turbidity in spring waters.

Alkalinity was not significantly different between the streams and the lake. In both of these the phenolphthalein alkalinity (carbonate alkalinity) was equal to zero, resulting in the Total Alkalinity equaling the bicarbonate alkalinity. Similar geologic formations are located beneath Raystown and the springs beds with minor amounts of limestone and other carbonates present in each, therefore, geologic composition would have little to no affect on the alkalinity levels. Alkalinity serves to protect the aquatic environment form rapid changes in pH. For optimal protection of aquatic life the buffering capacity should be at least 20 mg/l. (Horne1994) The low alkalinity numbers show that streams are poorly buffered and could be susceptible to fluctuations in pH.

Although my results indicate no difference between the Scherr and Foreknobs formations, a clearer picture is available of what may be going on with Raystown Lake. The streams feeding the lake are relatively similar to the quality of the lake leaving little effect on the water quality. The determination of low alkalinity levels should be studied further to confirm this finding. Further study may also include testing for nitrates, phosphorus, iron and magnesium as well as repeating the experiment during low flow in the summer.

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