Water Quality Assessment and Report of Paradise Brook Watershed and Red Maple Pond at Norman Bird Sanctuary, Middletown, Rhode Island

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Abstract

Contaminated water has been known to pose serious health risks to humans and reduce the area's biodiversity. Water can become polluted in various ways by both humans and naturally occurring processes. In this study, water samples were taken from five sites on the grounds of Norman Bird Sanctuary in Middletown, Rhode Island and tested in the lab at Salve Regina University. Dissolved oxygen, total nitrogen, phosphate, and E. coli levels were measured to determine the health of the watershed. It was previously determined that Paradise Brook is an impaired watershed, most likely due to the horse farm located upstream. The findings were also compared to the daily rainfall accumulation, as any amount of rain over 0.635 cm has been found to cause runoff of nutrients and unwanted contaminants to flow into other water areas and contaminate them. The dissolved oxygen levels were over six ppm for every sample at each site. The total nitrogen levels were consistently over the Rhode Island standard range of 0.75 mg/L. The phosphorus levels were also consistently over the Rhode Island standard of 0.25 mg/L, except for a few sample sites. Finally, the E. coli levels were all under the Rhode Island standard except for the samples taken on March 24th. However, this can be attributed to high levels of rainfall the previous day. Therefore, each of the sample sites flowing through Norman Bird Sanctuary were found to have elevated levels of total nitrogen and phosphate, but overall safe and healthy levels of dissolved oxygen and E. coli.

Background

Water is essential to the health and well-being of all living beings, from humans to animals and plants; therefore, it is important for water to be safe and clean. Water quality refers to the physical, chemical, and biological properties of water that determine its sustainability for various purposes (Tyagi et al., 2013). Water is considered polluted when its quality has deteriorated due to the introduction of foreign materials through natural factors, such as weather and geological conditions, and/or human activities, including agriculture and urbanization (Awomeso et al.,2010). Polluted water can cause illness and even death in humans and animals and disrupt entire ecosystems by harming aquatic and terrestrial life through the reduction of available clean water (Ritchie & Roser, 2021). Therefore, ensuring water quality is crucial for maintaining the health and well-being of our planet's ecosystems and the organisms that depend on them. By addressing water quality issues, we can protect the environment, improve human health, and promote sustainable economic development.

To examine the health of a watershed, the following levels are measured: dissolved oxygen, total nitrogen, phosphate, and *E. coli* (Tyagi et al., 2013). Dissolved oxygen is the measure of how much oxygen is dissolved in the water. Low dissolved oxygen levels can cause organisms to not able to complete cellular respiration and not produce enough energy, ultimately leading to their death (*Dissolved Oxygen and Temperature*). Inadequate levels of dissolved oxygen can also slow down the process of decomposition, creating a buildup of organic matter in the water, leading to an overall decline in water quality (U.S. Geological Survey, n.d.).

Moreover, total nitrogen is typically present in bodies of water and is a result of the naturally occurring nitrogen cycle; however, excess levels can occur and have been tied to a biological process called eutrophication (Khan & Mohammad, 2013). Eutrophication is characterized by an excess nutrient load that increases the amount of algal growth, ultimately decreasing the water clarity, dissolved oxygen levels, marine populations, and overall water quality (Khan & Mohammad, 2013). Furthermore, phosphate is an essential nutrient for plants and animals, however when it is found in excessive amounts it can cause an overgrowth of aquatic plants and algae (DES 2019). This excessive growth leads to a variety of water quality problems such as low dissolved oxygen levels and eutrophication. Lastly, E. coli is an indicator for fecal coliform pollution, which is one of the more frequent microbial contaminants that plague water sources around the world. The presence of fecal contamination in water sources can cause numerous health hazards including skin and eve irritation, nausea, vomiting, diarrhea, stomach cramps, and related diseases including Diarrhoeal, which claims the lives of 525,000 children under five years old every year (World Health Organization, 2017). Elevated levels of E. coli indicate an impaired watershed. Moreover, precipitation levels can heavily affect the concentrations of all these previously discussed characteristics of water. After heavy rainfall, it is typical for nitrate, phosphate, dissolved oxygen, and E. coli levels to rise in watersheds.

Norman Bird Sanctuary in Middletown, RI, was established in 1949 as a nonprofit wildlife sanctuary and environmental education center, composed of 325 acres of diverse land (Norman Bird Sanctuary, n.d., Figure 1).



Figure 1. A map of Norman Bird Sanctuary and the hiking trails throughout the property.

Paradise Brook is a 2.5-mile-long stream that flows along the outer edge of the sanctuary's property and located downstream from the Newport Equestrian facility (RIDEM, 2017). According to an assessment conducted by the Rhode Island Department of Environmental Management (RIDEM), Paradise Brook was found to have elevated levels of both enterococci and *E. coli* and was therefore classified as an impaired watershed, the source of pollution was likely due to runoff containing animal fecal matter from the Equestrian facility (RIDEM, 2017). Red Maple Pond is another watershed that flows within Norman Bird Sanctuary and is located along the Universally Accessible Trail. Red Maple Pond is home to diverse wildlife and frequently visited by the public and utilized by children during summer camp programs, therefore its health is imperative to humans, animals, and plants, alike. Staff at Norman Bird Sanctuary were concerned the water quality of Red Maple Pond had declined for reasons similar to those identified by RIDEM for the impairment of Paradise Brook. Therefore, students in Dr. Jameson Chace's Conservation Biology class at Salve Regina University were recruited to assess the water quality of Red Maple Pond, and if contamination is detected, to determine the source of pollution.

Methods

Study Sites

Norman Bird Sanctuary is composed of 325 acres of land and 7 miles of marked hiking trails (Figure 1). Red Maple Pond is a central attraction where visitors can overlook the abundant wildlife that live in the pond. Red Maple Pond is found along the Universally Accessible walking trail. In order to assess the water quality of this watershed, five different sample location sites were established in this study. The first three sample sites were located within the boundaries of Norman Bird Sanctuary, while the remaining two sites were located on the side of Hanging Rock Road. Site 1 was at the bridge along the Gray Craig Trail where the trail intersected the stream flow into Nelson Pond. Site 2 was placed off the beginning of the Woodcock Trail and was located upstream of the central pond. Site 3 was the actual pond found along the Universally Accessible Trail. Site 4 was located downstream of the central Red Maple Pond along the side of Hanging Rock Road. Lastly, site 5 was found further down Hanging Rock Road at the intersection of the Red Maple Pond and the Maidford River flows that discharged into Third Beach.



Figure 2. A map of the hiking trails in Norman Bird Sanctuary and the location of the three sample sites along the Red Maple Pond watershed that are contained within the boundaries of Norman Bird Sanctuary.



Figure 3. A map displaying Hanging Rock Road running along the border and leading to Norman Bird Sanctuary and demonstrating the location of the remaining two sample sites of Red Maple Pond.

Field Sampling Protocol

Prior to collecting the water samples, a bag was packed containing the corresponding collection bottles, the field notebook, gloves, and a thermometer. Three different bottles were required for water collection at each site location in order to assess the dissolved oxygen, nutrients, and *E. coli* levels of the samples without cross-contamination. The bottles utilized to collect water for *E. coli* examination were autoclaved in order to sterilize the interior and ensure the most accurate findings in regard to fecal pollution. Another individual bottle was used in order to collect samples for total nitrogen and phosphate nutrient tests, and lastly, a small bottle was used to gather the water for dissolved oxygen tests. Furthermore, all bottles were acid washed to make sure only the desired water samples contaminated the interior of the bottles and there was no other leftover water from previous uses. Gloves were worn when collecting the water samples to ensure the safety of the researchers. In the dissolved oxygen samples, 8 drops

of manganous sulfate solution, alkaline potassium iodide azide, and sulfuric acid were deposited in order to fix the oxygen in the sample for the remaining steps of the test. Air and water temperature, along with observations on the water flow and clarity were recorded in the field notebook during the time of sample collection. Rain gauges were placed at sites 1, 2, and 4 in order to measure the level of rainfall at Norman Bird Sanctuary over the sampling period. Researchers gathered water samples at all site locations during dry and wet weather events in order to observe how rainfall alters the measured nutrient, *E. coli*, and dissolved oxygen levels of the water.

Lab Test Protocol

When the samples are brought to the lab, they are immediately placed in the refrigerator to ensure that no growth occurs that could affect the results of the study. These samples are then tested for dissolved oxygen, phosphate, total nitroge, and *E. coli*. Using the LaMotte test kit, the team is able to test for the amount of dissolved oxygen in the samples brought back from the Norman Bird Sanctuary. Using Hach test kits, the team is able to test for total nitrogen and phosphate in the water as well. These tests are to be completed within a week of when the sample is collected. The final test to be conducted measures *E. coli* levels within the water. This is a time sensitive test that should be completed within hours of sample collection. *E.coli* is tested by using membrane filtration and modified membrane thermotolerant *Escherichia coli* agar (modified mTEC) systems. The samples are understood by a set of ratios dependent on the amount of water that is put in the filtration system. These ratios are 1:1, 1:10, 1:100, and 1:1000. Once the plates are completed they are placed into dry incubation for 24 hours and then wet incubation for 2 hours. Finally, the agar plates are taken out and colonies are counted in each.

Results

The daily rain accumulation was recorded daily from February 23 to March 29. All the data points were below 0.635 cm (0.25 inch), indicating the rain was not enough to impact stream flow (J. Manning *peers. Comm.*), except for February 23 and 27 and March 4, 14, 22, 23, and 25. On February 23rd it rained 1.01 cm (Figure 4). Rainfall impacted flow more one some days (March 24, 1 day after rain) more than others (March 2, 3 days after rain; (March 8, 4 days after rain) (Figure 4). All samples were collected on February 24, March 3rd, March 10th, and March 24th. On February 27th it rained 0.86 cm. On March 4th it rained 2.18 cm. On March 14th it rained 3.82 cm. On March 22 it rained .71 cm. On March 23rd it rained 1.2 cm. On March 25th it rained 2.4 cm (Figure 4).

Dissolved oxygen tests were conducted on February 24th, March 3rd, March 10th and March 24th. The levels of dissolved oxygen were over 6 ppm (parts per million) for every sample at each site (Figure 5). Total nitrogen levels were tested on the same days. A total nitrogen level of over 0.75 mg/L is over the standard range for Rhode Island. Each sample site was over this level on every sample day (Figure 6). Phosphorus levels were tested and compared to the Rhode Island standard of 0.025 mg/L. At site one the phosphorus levels were over this standard for

every sample collected. At site two, all of the samples were over this standard except for March 8^{th,} with the levels being 0.04 mg/L. At site three they were all over this standard except for March 2nd with the levels being 0.08 mg/L. At site four the levels were over the standard for every sample collected. For site four the levels were all over this standard except for February 22 with the level being 0.2 mg/L. *E. Coli* levels were measured on March 2nd, 8th and 24th. The dashed line at 126 cfu/100mL represents the EPA upper limit for impaired water. All of our data was below that line except for March 24th at sites 2 and 5 (Figure 7). The March 24 collection was impacted by the rain causing the *E. Coli* levels to spike (Figure 8 and 4).



Daily Rain Accumulation

Figure 4. Daily rain accumulation measured in centimeters from February 23 to March 29, 2023, Middletown, RI. The dashed line at 0.635 cm represents the amount of rainfall needed to impact runoff and other testing levels.

Dissolved Oxygen



Figure 5. Dissolved Oxygen Levels measured in parts per million(ppm) at each of the five sites on February 24th, March 3rd, March 10th, and March 24th, 2023, Middletown, RI. The standard for dissolved oxygen levels is 6 ppm which is noted by the dashed line.



Figure 6. Total nitrogen levels measured in mg/L measured at each of the five sites, Middletown, RI, over three testing days: March 2, March 8, and March 22, 2023 in Middletown, RI. The standard for total nitrogen in streams in the state of Rhode Island is 0.75mg/L.





Figure 7. Total Phosphate levels measured in mg/L measured at each of the five sites over three testing days: February 22, March 2, March 8, and March 22, 2023, Middletown, RI. The standard for Total Phosphate levels in streams in the state of Rhode Island is 0.25 mg/L



Figure 8. Total number of *E. coli* colony forming units (cfu) measured at each of the five sites, Middletown, RI, on March 2, March 8, and March 24 in 2023, Middletown RI. The dashed line represents 126 cfu/100 mL, the EPA upper limit for impaired water.

Discussion

The results of the dissolved oxygen testing conducted on the water samples taken from all 5 sites on the NBS property show that the dissolved oxygen levels did not drop below 8 ppm on any of the testing days (February 24th, March 3rd, March 10th, and March 24th, 2023). This is a positive indication that the water is suitable for supporting a high abundance of species. particularly fish (Dissolved oxygen in water). The standard dissolved oxygen level required for aquatic life to thrive is around 5 to 6 ppm (Dissolved oxygen in water). If levels start to drop below this standard level, then fish and other species will become stressed and struggle to survive, if it drops below 2ppm they will die. The fact that the dissolved oxygen levels in the NBS property water samples were consistently higher than the standard levels is encouraging. This suggests that the water has a healthy environment that can support a diverse range of aquatic life. It is important to note that high levels of dissolved oxygen are to be expected during the months of February and March when the water temperature is lower. Cold water can hold more DO than compared to warm water during the summer and fall months (Dissolved oxygen and water completed). Overall, the findings suggest that the water on the NBS property had good levels of DO that can support a healthy ecosystem. This is not taking into consideration the other water quality tests. Further testing and monitoring of the DO levels should be conducted periodically to ensure that the DO levels remain at a suitable level for aquatic life during the warmer months.

Moreover, on almost every sample date, all the sample sites exhibited elevated total nitrogen levels over the USEPA standard of 0.75 mg/L for safe recreational waters. This indicates that there is an improper level of total nitrogen in the Paradise Brook watershed and Red Maple Pond at Norman Bird Sanctuary, making it inadequate for recreation, but also unsuitable for a diverse ecosystem. Excess levels of total nitrogen can lead to eutrophication, which is an overgrowth of aquatic plants, like algae, that can lead to algae blooms. When aquatic plants, like algae, die, a large amount of oxygen is absorbed during the decomposition process, taking away the oxygen from other aquatic species. Therefore, causing a dead zone, where there is not enough oxygen present in the water to sustain life (Water Resources Mission Area, 2019). Although there was no clear visual evidence of an algal bloom in the sampled areas of Paradise Brook and Red Maple Pond, the total nitrogen levels indicate a potential for a eutrophic event.

Although the phosphate levels were more sporadic throughout the sampling days than the measured dissolved oxygen and total nitrogen levels, the phosphate levels remained above the USEPA standard for recreational waters of 0.25 mg/L for the majority of the sampling days at all sites, further indicating elevated nutrient levels in Paradise Brook and Red Maple Pond in Norman Bird Sanctuary. Similar to increased total nitrogen levels, excess phosphate levels in a watershed also cause eutrophication that can lead to dead zones unable to maintain life. This further reveals a problem of elevated nutrients in the water quality of Paradise Brook and Red Maple Pond.

Furthermore, the overall *E. coli* levels measured were consistently under the USEPA standard of 126 cfu/ 100 mL, indicating there to be no fecal contamination and the waters safe

for recreation in Red Maple Pond and Paradise Brook. On the sample day March 24, 2023, the levels of *E. coli* were measured to be above the USEPA standard at sites 2 and 5, which was inconsistent with the overall measured levels. This was likely due to the rainfall levels, on March 24 there was a precipitation event causing an increase in the levels of contaminants in the studied watersheds.

A portion of the Paradise Brook watershed and Red Maple Pond is located within Norman Bird Sanctuary, Middletown, RI. Norman Bird Sanctuary contains multiple hiking trails that run alongside the previously identified watersheds and hosts a camp for children during the summer in which the children utilize the waters for recreation. In addition, the sanctuary is home to a wide variety of wildlife, therefore, it is important to maintain the water quality of the watersheds within Norman Bird Sanctuary to ensure the safety of the community both animal and human. As a result, students apart of the Conservation Biology course at Salve Regina University assessed the water quality of Paradise Brook and Red Maple Pond in Norman Bird Sanctuary. The watersheds were found to have elevated nutrient levels of total nitrogen and phosphate, however, the measured *E. coli* and dissolved oxygen levels were safe for recreational waters according to the USEPA standards. This study was performed over a month and a half; therefore, further sampling and testing should be performed in order to gain a more conclusive analysis of the water quality of Paradise Brook and Red Maple Pond.

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