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

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Abstract

Water contamination is an increasingly prevalent issue, and although natural causes can occur, anthropogenic causes, including industrialization and urbanization, are the main drivers. Norman Bird Sanctuary, located in Middletown, Rhode Island, was established in 1949, and since then has become increasingly surrounded by dense residential, commercial, and agricultural properties. A study conducted in 2017 by the Rhode Island Department of Environmental Management identified the Maidford River and Paradise Brook as impaired watersheds, portions of which flow through the Norman Bird Sanctuary property. Furthermore, Red Maple Pond and the portions of Paradise Brook found within Norman Bird Sanctuary are commonly utilized for recreational and educational uses, and are vital to the well-being of the wildlife species within the sanctuary. The purpose of this research was to assess the water quality of Red Maple Pond and Lower Paradise Brook by measuring the levels of dissolved oxygen, total nitrogen, total phosphorus, and *E. coli.* Samples were taken from 6 different sites, and all exhibited water quality indicator levels above the USEPA standard for recreational waters. Therefore, Red Maple Pond and portions of Paradise Brook flowing through Norman Bird Sanctuary were concluded to be impaired.

Introduction

Water Pollution

Water is a vital resource for all living things; consequently, there is a high demand for sources of safe drinking water. Only 3% of Earth's water supply is considered fresh; however, of that percentage only 0.5% is accessible for consumption, with the remaining 2.5% being trapped in polar ice caps and glaciers, therefore, fresh surface water sources are naturally in low supply.[1] The lack of availability of clean water is exacerbated even more due to issues including climate change, population growth, environmental degradation, and an increase in overall consumption.[2] These problems lead to water pollution, which is when foreign materials are introduced and cause the quality of water to deteriorate.[3] Inorganic chemicals, like nitrate and phosphate, microorganisms, and volatile organic chemicals are among the most common water pollutants found.[4] Potential sources of these contaminants include point sources, like human sewage and industrial facilities, and nonpoint sources, like urban and agricultural runoff.[4]

Water Quality Assessment

Contaminated water sources can pose a serious threat to human health if consumed and can degrade entire ecosystems; therefore, it is important to assess the quality of a watershed.[5] To do so, various indicators are measured in order to determine the health of a water source. These indicators include dissolved oxygen, total nitrogen, phosphate, and *Escherichia coli* (*E. coli*). Dissolved oxygen is the amount of oxygen that is available in water, and it is required by all aquatic animals for survival; therefore, dissolved oxygen serves as an indicator of a watershed's ability to support aquatic life.[6] Low levels of dissolved oxygen are typically a direct result of a large amount of plant, or other organic material, being decomposed in a water source, causing the available dissolved oxygen to be absorbed during the decomposition process.[6] Nitrogen and

phosphorus are nutrients required for all life; however, they are also considered limiting nutrients because when either are in high concentration it can cause an overgrowth of aquatic plants and algae, leading to a decline in dissolved oxygen levels and overall ecological health of a watershed.[7, 8] Both nutrients occur naturally in the environment, but they are also found in anthropogenic sources, most commonly fertilizers.[7, 8] *E. coli* is an indicator of fecal contamination in a water resource, and its detection reveals whether water is safe for human consumption.[9] When consumed, *E. coli* and other microbial contaminants can cause intestinal infections including diarrhoea.[9] After heavy precipitation, the measured levels of these water quality indicators tend to rise as a direct result of runoff, or stormwater, from neighboring residential areas or agricultural sites.[10]

Norman Bird Sanctuary

Norman Bird Sanctuary is a nonprofit organization established in 1949 and is located in Middletown, Rhode Island.[11] It serves as a wildlife sanctuary, environmental education center, and a place of recreation. Norman Bird Sanctuary is composed of over 300 acres of land with diverse ecosystems, and over 7 miles of trails to explore the property.[11] Paradise Brook is a 2.5 mile long stream that flows along with west side of Third Beach Road, through a dense residential area, and continues downstream from the Newport Equestrian facility, where Paradise Brook flows through the forested south-southwest region of Norman Bird Sanctuary property, and deposits into Nelson Pond.[12] Nelson Pond then discharges and converges with the Lower Maidford River before depositing into Third Beach. According to a study conducted in 2017 by the Rhode Island Department of Environmental Management (RIDEM), Paradise Brook was found to have consistently elevated levels of total phosphorus, total nitrogen, enterococci, and *E. coli*; therefore, Paradise Brook was classified as an impaired watershed.[12] The source of this pollution was likely due to runoff from the neighboring residential, commercial, and agricultural sites.[12] Moreover, Red Maple Pond is a watershed located within Norman Bird Sanctuary along the Universal Trail, downstream from the Newport Equestrian facility, and it discharges into the Lower Maidford River before flowing into Third Beach. Although not directly connected to Paradise Brook, during high rain events portions of Paradise Brook can overflow and converge into parts of Red Maple Pond. The degradation of Red Maple Pond's water quality poses a threat to both the human and animal members of Norman Bird Sanctuary's community; in addition, to the residents of Rhode Island and tourists at large due to the watershed's discharge location being into the public waters of third beach. Red Maple Pond is utilized in educational programs during summer camp and field trips where children learn about the watershed by wading into the water or using nets. Furthermore, countless wildlife species, both terrestrial and aquatic, heavily depend on Red Maple Pond for survival, either as a drinking source or even as a habitat.

Purpose of Research

In an effort to prevent similar water impairment outlined in RIDEM's 2017 report of Paradise Brook and Maidford River, concerns were raised for the water quality of Red Maple Pond due to its location downstream from agricultural sites and a horse farm. Therefore, the

purpose of this study was to assess the overall water quality of Red Maple Pond and portions of Paradise Brook found within Norman Bird Sanctuary.

Materials and Methods

Water Sample Site Locations

To assess the water quality of the Red Maple Pond and Lower Paradise Brook watershed, six different sample sites were established. The first three sample sites were located on Norman Bird Sanctuary Property, while the remaining three sites were located off the sanctuary's property. Site 1 was located along Gray Craig Trail on the boardwalk where the trail intersected the Paradise Brook stream before discharging into Nelson Pond (41.499258, -71.257819) (Figure 1). Site 2 was the inlet of Red Maple Pond and located in the woods off the beginning of the Woodcock Trail (41.498534, -71.255517) (Figure 1). Site 3 was the main portion of Red Maple Pond found along the Universal Access Trail (41.497698, -71.255500) (Figure 1).

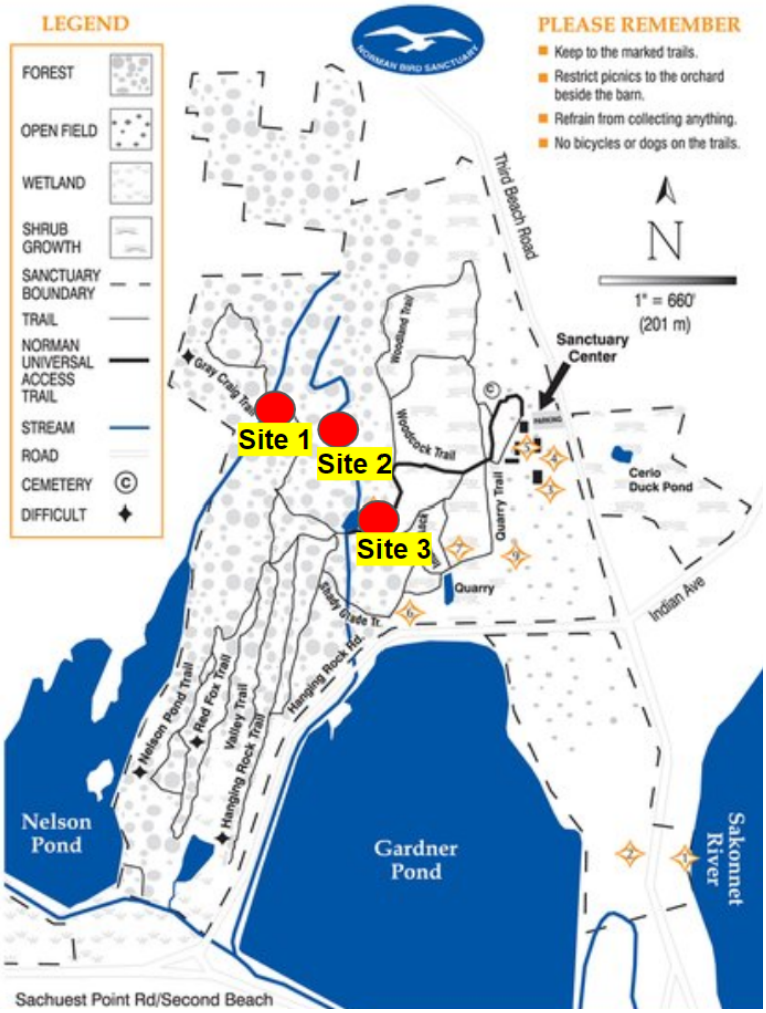

Figure 1. A map displaying Norman Bird Sanctuary's hiking trails and the location of the first three sample sites relative to the trails.

Furthermore, site 4 was considered the outlet of Red Maple Pond located downstream from site 3 off to the side of Hanging Rock Road (41.495457, -71.255619) (Figure 2). Site 5 was the intersection point of the Lower Maidford River with the Red Maple Pond outlet found further down Hanging Rock Road (41.490237, -71.258773) (Figure 2). Lastly, site 6 was located above Newport Equestrian Academy to the side of Green End Avenue (41.509639, -71.255683) (Figure 3).

Figure 2. A map depicting the outlet of Red Maple Pond along Hanging Rock Road and where it flows into the Lower Maidford River, in addition to the location of sample sites 4 and 5.

Figure 3. A map displaying Paradise Brook running alongside Third Beach Road upstream from Newport Equestrian Academy and demonstrating the location of sample site 6.

Water Collection Technique

Water samples were collected midday every Tuesday between September 21, 2023 and October 31, 2023. Prior to going into the field, a bag was packed containing the required collection bottles, field notebook, gloves, and a thermometer. For every site, three separate bottles were utilized, one to collect water to test for total nitrogen and phosphorus, another to examine the dissolved oxygen in the sample collected, and the third to hold water to bring back to the lab for *E. coli* measurements. The first two bottles mentioned were sterilized using an acid wash before being utilized in the field; the third bottle was sterilized using the autoclave machine to ensure no other bacteria contaminated the sample. Upon arrival at the site, the researcher recorded the time, location, date, weather, air and water temperature, along with observations on the water flow and clarity in the field notebook. The water samples were collected by hand on the surface of the water, or 6-12 inches below the water surface. During collection, the sample bottles were positioned with the mouth directed toward the flow of water, and each bottle was rinsed 2-3 times with the sample before being filled. Rinsing the interior of the bottles further ensured only the desired sample water contaminated the collection container. Furthermore, gloves were worn during the water collection process as a safety precaution. To fix the dissolved oxygen in the collected sample, 8 drops of manganous sulfate solution, alkaline potassium iodide azide, and sulfuric acid were deposited.

Water Sample Handling and Storage

After collection, the water samples were brought back to the lab and immediately stored in the refrigerator at a temperature of less than 10℃ until analysis. The water collected to measure *E. coli* levels was preferred to be evaluated immediately upon arrival to the lab, however, *E. coli* samples were allowed to be refrigerated for up to 24 hours before analysis.

Water Quality Assessment Protocol in Lab

To measure the dissolved oxygen in the collected samples, the LaMotte test kit and its procedure was utilized. Hach test kits and their corresponding protocols were utilized to measure the total nitrogen and total phosphorus levels. The final assessment to be conducted measured *E. coli* levels using membrane filtration and modified membrane thermotolerant *Escherichia coli* agar (modified mTEC) systems.[13]

Statistical Analysis

The measured levels of dissolved oxygen for each of the sites during the sampling period was then averaged. The standard deviation and standard error for each site's average was then calculated to determine the variation and consistency of the data. These values were also calculated for Total Nitrogen, Total Phosphorus, and *E. coli*.

Results

Daily Precipitation Levels

The daily rainfall levels were recorded daily during the sampling period of this project. This data was retrieved from the online reports of National Oceanic and Atmospheric Administration's (NOAA) weather service station located at the Newport State Airport in Middletown, RI.[14] The standard amount of precipitation required to cause runoff and influence stream flow rates is 0.635 cm. Most days during the sampling period had no rainfall, or rainfall levels below 0.635 cm; however, on September 23-25, October 21, and October 29-30, the rainfall levels well exceeded the established standard indicating stream flow of the examined watershed was likely impacted (Figure 4).

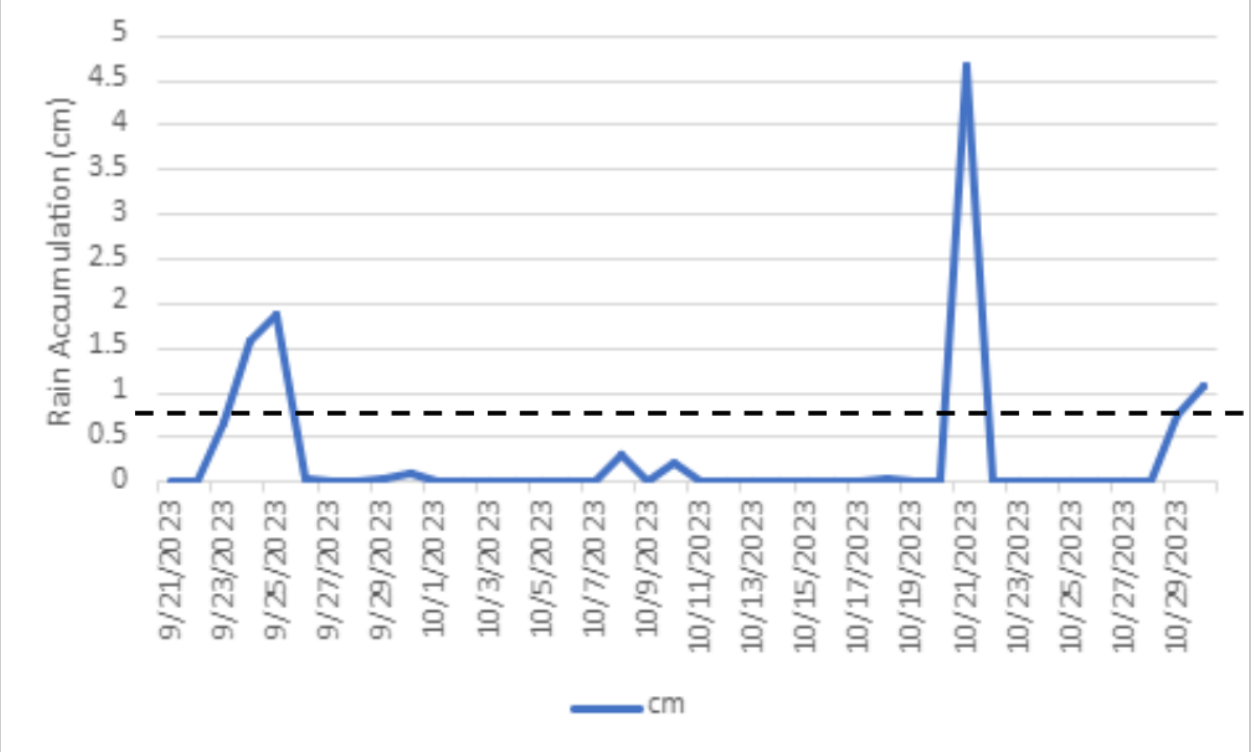

Figure 4. Daily rain accumulation measured in centimeters from September 21, 2023 to October 31, 2023. The dashed line at 0.635 cm represents the amount of rainfall required to impact runoff, thereby affecting water quality indicator levels.

Dissolved Oxygen

According to the RIDEM, the standard level of dissolved oxygen required for survival of aquatic life in recreational freshwaters is a minimum of 6 ppm.[15] Sample sites 1, 2, and 6 were found to have levels that exceeded the RIDEM standard; whereas, sites 3, 4, and 5 had average levels below 6 ppm, indicating a lack of oxygen available to aquatic life inhabiting these sites (Figure 5).

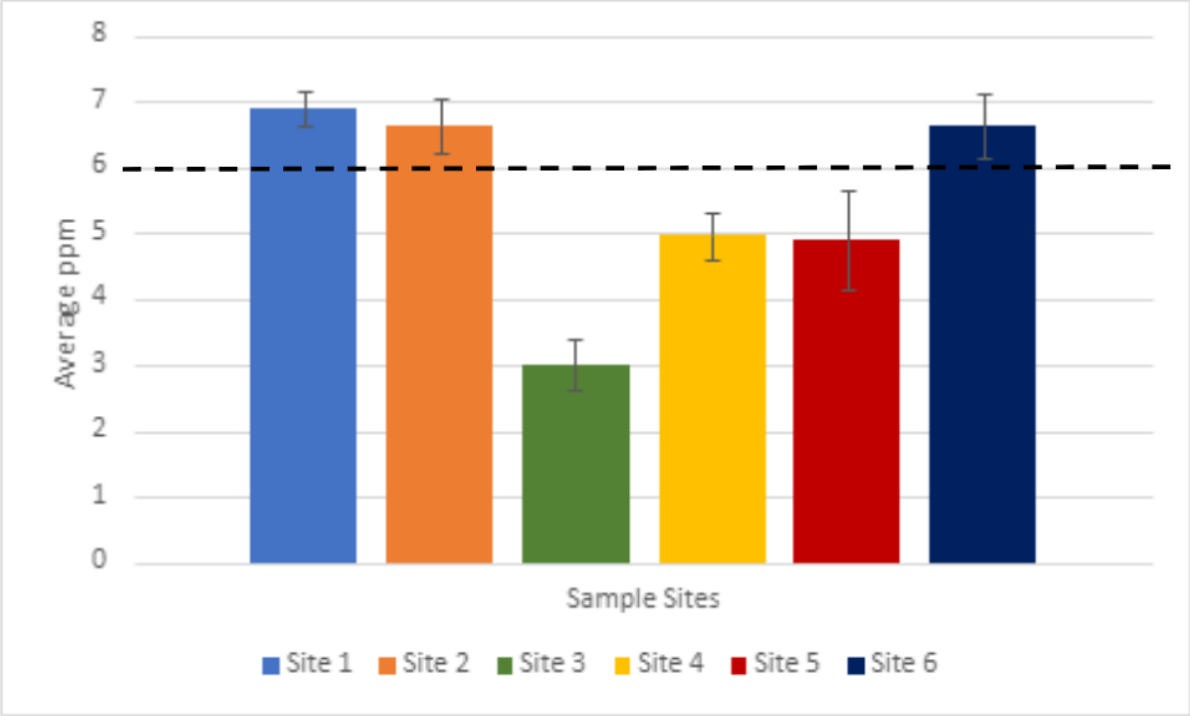

Figure 5. Average level of Dissolved Oxygen in parts per million (ppm) measured at each of the six sample sites. The dashed line at 6 ppm represents the RIDEM standard for Dissolved Oxygen in recreational waters.

Total Nitrogen

As defined by the RIDEM, the maximum amount of total nitrogen allowed for recreational freshwater sources to be considered safe is 0.75 mg/L.[15] The measured levels of total nitrogen at all sample sites were found to well exceed the RIDEM standard, with Site 2 having the highest average amount of 2.514 mg/L and Site 5 demonstrating the lowest average of 1.429 mg/L (Figure 6).

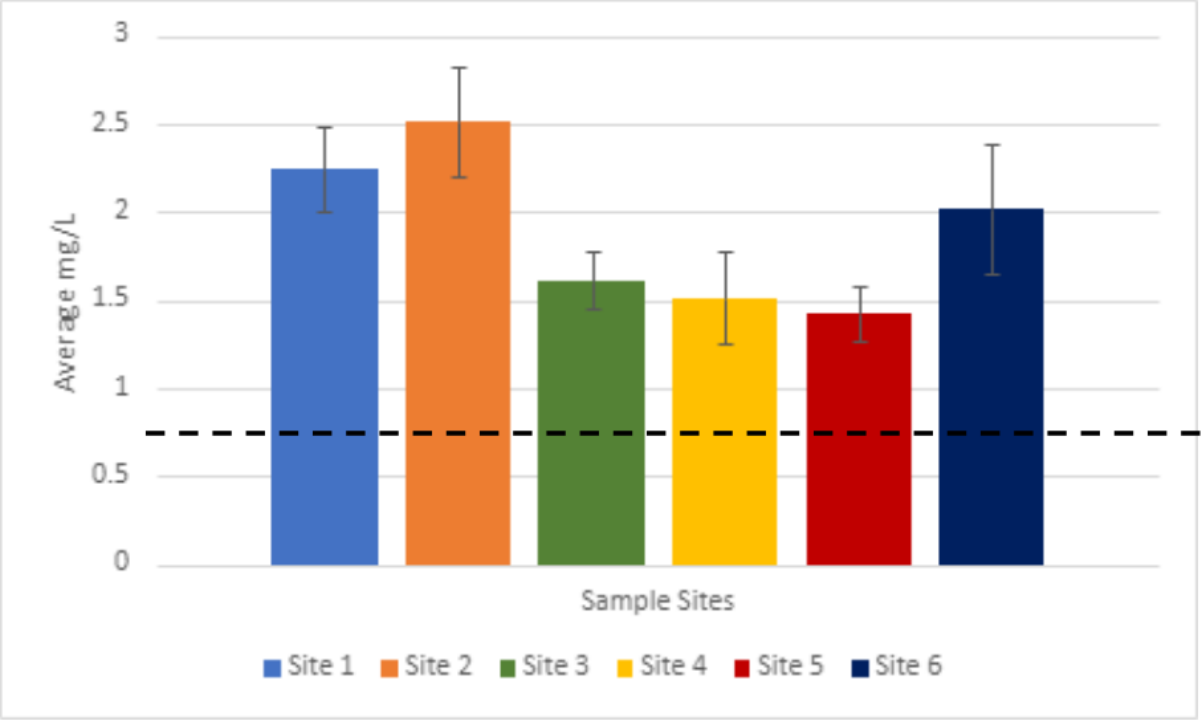

Figure 6. Average level of Total Nitrogen in milligrams per liter (mg/L) measured at each sample site. The state of Rhode Island standard, as defined by RIDEM, for total nitrogen in streams is denoted by a dashed line at 0.75 mg/L.

Total Phosphorus

The RIDEM limit for total phosphate in recreational freshwater sources is 0.025 mg/L.[15] The measured levels of total phosphorus for all sample sites significantly exceeded the defined standard, with site 6 having the highest average level of 1.116 mg/L and site 3 demonstrating the lowest average of 0.578571 mg/L (Figure 7).

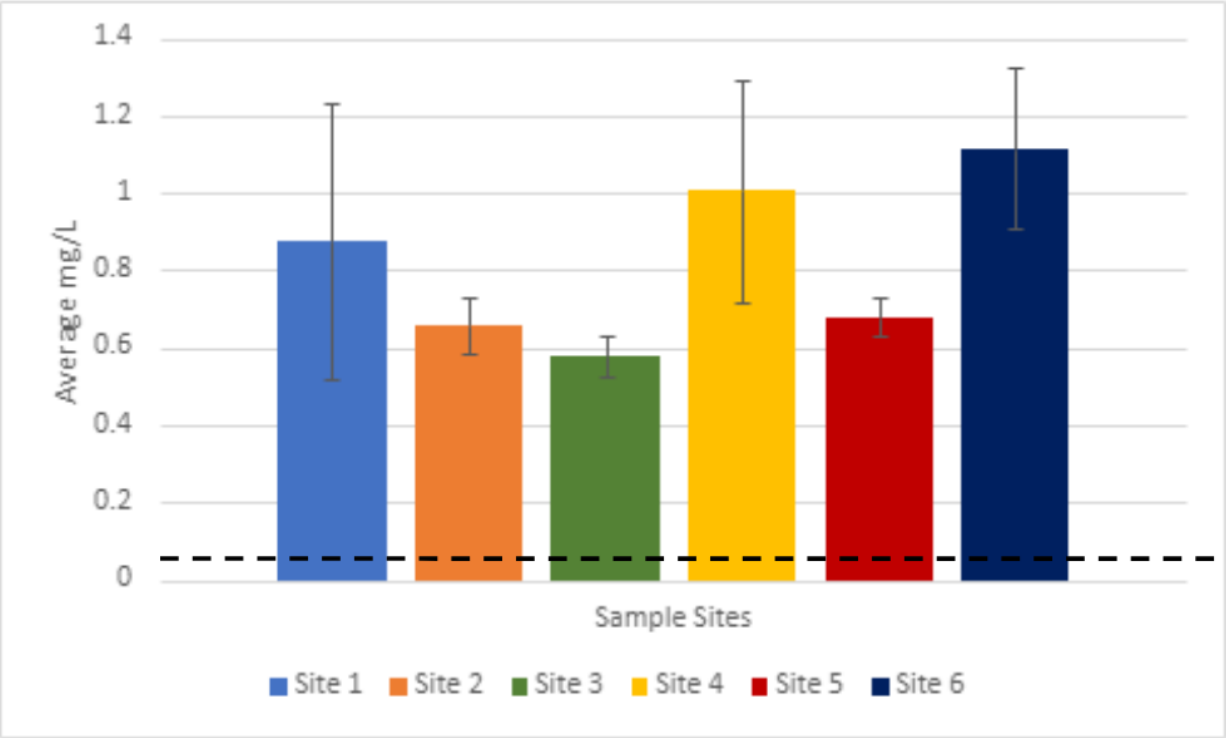

Figure 7. Average level of Total Phosphate in milligrams per liter (mg/L) measured at each of the six sample sites. According to RIDEM, the standard for total phosphate in streams in the state of Rhode Island is 0.025 mg/L, which is demonstrated by a dashed line.

E. coli

According to the RIDEM, the upper limit of *E. coli* for impaired recreational freshwater is 126 cfu/100 mL.[15] All sample sites demonstrated averages well above the defined standard of *E. coli*, with site 2 exhibiting the highest overall average of 2088.33 cfu/100 mL and site 4 showing the lowest average of 352 cfu/100 mL (Figure 8).

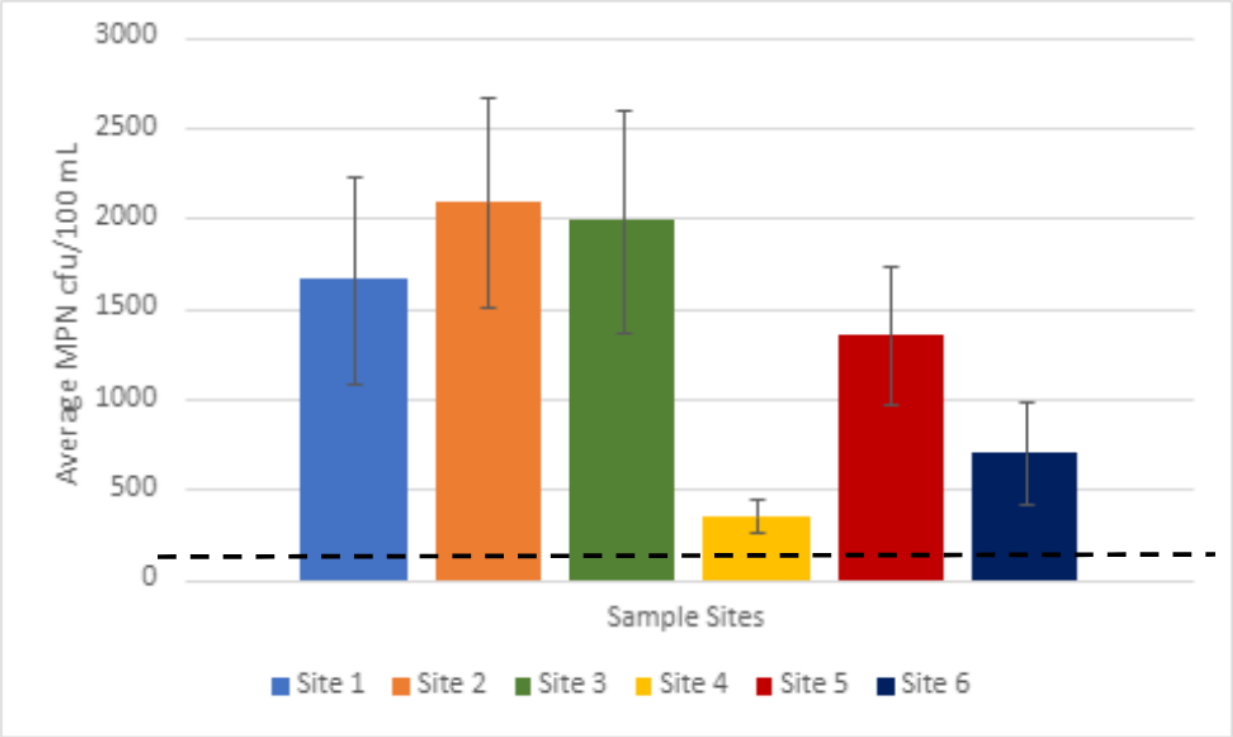

Figure 8. Average number of *E. coli* colony forming units (cfu) per 100 mL measured at each sample site. The dashed line demonstrates 126 cfu/100 mL, the upper limit of *E. coli* in a watershed as defined by the RIDEM.

Discussion

Norman Bird Sanctuary is composed of multiple watersheds including the lower portion of Paradise Brook and Red Maple Pond. In 2017, RIDEM classified Paradise Brook and the Maidford River as an impaired watershed due to the consistently elevated levels of phosphate, nitrate, enterococci, and *E. coli*.[12] Although Red Maple Pond and Paradise Brook were not directly connected, these water sources were both located downstream from the Newport Equestrian Academy and other numerous agricultural farms previously identified by RIDEM as potential sources of water pollution; therefore, their quality of water was expected to follow a similar pattern.

To analyze the water quality of the watersheds present in Norman Bird Sanctuary, samples were collected weekly between September 21 and October 31, 2023 from six sites and the levels of dissolved oxygen, total nitrogen, total phosphorus, and E. coli were measured. Daily precipitation levels were also recorded during the sampling period to determine whether abnormal spikes in water quality indicator levels correlated to increased levels of rainfall. Based on the data, September 23-25, October 21, and October 29-30 were the days during the sampling period in which the precipitation levels exceeded 0.635 cm, the amount of rainfall required to impact streams (Figure 4). The samples collected within 48 hours of these high precipitation events exhibited water quality indicator levels higher than usual, demonstrating the correlation between high rainfall levels and a decrease in water quality. However, it was concluded that high

precipitation events were not the main cause for water quality indicator levels exceeding the USEPA standards for safe recreational waters in this study due to the measured indicator levels being consistently above the corresponding standard.

Dissolved oxygen is the concentration of oxygen present in water that is available for use by aquatic life.[16] In this study, the average dissolved oxygen levels for sites 1, 2, and 6 were above the USEPA standard of 6 ppm, indicating there was an adequate amount of oxygen available in the water to support healthy aquatic life (Figure 5). Whereas, sites 3, 4, and 5 exhibited levels below the standard and therefore demonstrated an inadequate amount of oxygen available to support aquatic life (Figure 5). As previously mentioned, low levels of dissolved oxygen are commonly attributed to a large amount of plant material being decomposed in a water source, as oxygen is absorbed during the decomposition process.[6] Additionally, streams with high flow rates typically have high levels of dissolved oxygen because the movement of water allows for easier aeration, or diffusion of oxygen.[16] At all the sites demonstrating low levels of dissolved oxygen, a large amount of plant matter was present. Site 3 was located at the central portion of Red Maple Pond, which was covered in duckweed throughout the sampling period, likely causing the depletion of dissolved oxygen. Similarly, sites 4 and 5 were located off of Hanging Rock Road at roadway culverts surrounded by dense vegetation, which could also result in low levels of dissolved oxygen. Furthermore, the water flow rate at sites 3, 4, and 5 was stagnant, or low, in comparison to the faster flow at sites 1, 2, and 6, which could also contribute to the low levels seen.

Total nitrogen is a limiting nutrient that occurs both naturally and synthetically in the environment. At high concentrations, total nitrogen can cause an overgrowth of organic material, resulting in low dissolved oxygen levels and an uninhabitable aquatic ecosystem.[7] In this study, sample sites 1, 2, 3, 4, and 5 were located downstream from both agricultural farms and a horse farm, and were therefore expected to have higher nutrients levels. Whereas, site 6, which remained downstream an agricultural site but upstream the horse farm, was expected to have lower total nitrogen levels due to having less pollutant stressors. Upon analysis, all sample sites were found to exhibit total nitrogen levels well above the RIDEM standard of 0.75 mg/L for safe recreational waters, with sites 1, 2, and 6 having the highest levels (Figure 6). Site 6 being among the sites with the most total nitrogen present indicated the agricultural farm as a bigger detriment to the watershed's nutrient levels rather than the horse farm, likely due to the more extensive use of fertilizers and pesticides.

Similar to nitrogen, total phosphorus is a naturally occurring nutrient required for life to exist; however, it is considered a limiting nutrient, that is commonly anthropogenically produced and utilized in fertilizers and pesticides that are often swept up in runoff and deposited in nearby surface water sources.[8] In this study, total phosphorus levels were found to be well over the RIDEM standard of 0.025 mg/L at all sample sites (Figure 7). Site 6 was expected to have lower levels of total phosphorus due to its location upstream the horse farm and downstream agricultural farms; however, it actually exhibited the highest average levels for total phosphorus. Thereby, indicating the agricultural sites located upstream site 6 as more aggressive pollutants to

the watersheds than the horse farm, likely due to the use of fertilizers and pesticides on the farm sites.

Lastly, *E. coli* is an indicator for fecal contamination in a watershed, and when present suggests a water source as unsafe for human consumption.[9] In this study, *E. coli* levels were measured for all sample sites and collectively were found to be above the RIDEM upper limit of 126 cfu/100 mL for recreational waters (Figure 8). Site 6 was expected to have the lowest average level of *E. coli* due to its location upstream of the horse farm; although site 6 did have low levels, site 4 was found to have the lowest levels of *E. coli* out of all the sites. Site 4 was the outlet of Red Maple Pond placed along Hanging Rock Road; its relatively isolated location was hard for most animals, both aquatic and terrestrial, to reach, which might have contributed to the low levels of *E. coli* measured. Furthermore, sites 1, 2, and 3, all sites located directly downstream from the horse farm, were found to have the highest levels of *E. coli*, indicating the horse farm as the main source of fecal contamination in these watersheds.

Based on the results of this study, Red Maple Pond and Lower Paradise Brook were found to have elevated levels of dissolved oxygen, total nitrogen, total phosphorus, and *E. coli*; therefore, suggesting the watersheds are impaired. This is likely a direct result of the watersheds being located downstream numerous agricultural farms and an equestrian academy, which employ fertilizers, pesticides, and faulty ways to remove horse and other animal's feces. Although probably not the most prominent sources, it is important to note the watersheds were also surrounded by dense residential areas and impermeable surfaces, not to mention the wildlife that frequent the sanctuary itself, also contributing to the overall decline in water quality.

Red Maple Pond, specifically, is commonly utilized in educational programs by Norman Bird Sanctuary, therefore, it is important further steps are taken to remediate the impaired water quality. There are numerous ways to aid in the process, including more effective riparian buffer zones and biochar nets. Buffer zones are implemented to prevent the movement of nutrients from agricultural land into surface waters.[17] If not already established, the agricultural farms upstream the watersheds can implement buffer strips to help filter out the nutrients before being deposited into the water; if buffer zones are pre-existing, more plants can be situated inside the zone to more effectively filter pollutants from runoff before reaching the watersheds. Moreover, biochar is another tool commonly utilized to combat pollutants spilling into waterways. Biochar is a charcoal-like substance made from organic waste that has great absorption properties, making it an effective option for water treatment as it filters nutrients and other contaminants.[18] Porous bags are often filled with biochar and placed within a stream to act as a type of net, or bridge, to filter and treat polluted water sources.

The water quality of Red Maple Pond and Lower Paradise Brook impact both the Norman Bird Sanctuary community and the overall public due to the watersheds serving as a place for human recreation, a drinking water source for wildlife species, as an educational tool, and an aesthetic area for visitors to appreciate nature. Furthermore, the watershed discharges into third beach, thereby affecting those who swim in the waters including both human and aquatic life. The purpose of this study was to assess the water quality of Red Maple Pond and portions of

Paradise Brook found within Norman Bird Sanctuary; based on the results of this study, it was determined that the examined watersheds are impaired. Therefore, further steps must be taken in order to treat the water sources including implementing more effective buffer zones, or possibly utilizing biochar nets to filter the water.

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