A Preliminary Assessment of Water Quality in the Toms River

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Abstract
Residents and visitors in both Pine Beach and Ocean Gate can easily utilize Barnegat Bay with several access points that provide amenities such as parking spaces, trash receptacles, playgrounds, and swimming beaches. However, at many of these locations, storm drains are present, making it potentially harmful to swim, especially following a rain event. In this study, water quality conditions were monitored along Toms River in Pine Beach and Ocean Gate over a 10-week sampling period. Parameters included bacteria colonies, water temperature, conductance, salinity, dissolved oxygen, pH, and chlorophyll-a. The bacterial health of each site was assessed by counting the amount of times each site surpassed 200 colonies / 100 mL EPA swimming standard for Fecal Coliforms. Avon Road in Pine Beach and Jeffrey's Creek in Ocean Gate were found to have the highest fecal bacterial counts, while Asbury Avenue and Stone Harbor Avenue had no detectable fecal bacteria throughout the study period. Based on this study, it is recommended that Avon Road and Jeffrey's Creek are routinely monitored for water quality conditions.

Introduction

The recreational value of Barnegat Bay attracts many tourists to the surrounding area in the summer. Of concern is the quality of the water many visitors frequently swim in, specifically the Toms River, which leads into Barnegat Bay. Because many of the beaches in this area are in close proximity to storm drain pipes, pollutants and bacteria, which enter storm drains through pet waste, litter, and other human factors, are commonly present (United States Environmental, 2019). Bacteria are naturally occurring in rivers, lakes, and streams, and most types are harmless to humans. However, some types of bacteria do pose a threat to human health and can cause illness when ingested or swimming in contaminated water. High levels of harmless bacteria can often indicate high levels of harmful bacteria, and therefore it is important to monitor the presence of bacteria in swimming water. The most concerning type of bacteria found in swimming water is *Escherichia coli (E. coli)* because it can cause illnesses such as meningitis, septicemia, urinary tract, and intestinal infections, as well as indicate sewage or animal waste contamination (USGS). After rain events, pollutants will collect in storm drains and contaminate the runoff that flows into the Toms River. The storm drains that carry this polluted water often deposit the runoff directly into swim zones, posing a risk to swimmers and beachgoers. Estuarine water quality is usually conducted using marine water quality protocols, so Enterococcus testing is considered the standard to determine *E.coli*. However, parts of the Toms River have low salinity values and during rainfall events, the salinity values can mimic a tidal freshwater system, thus testing for Fecal Coliform bacteria was used in this study. The purpose of this study is to provide water quality data in order to locate and determine the extent of any water quality

impairments in Toms River so that remediation can be enacted if necessary. This study will be completed in three phases over three summers to address the water quality of the townships of Ocean Gate, Pine Beach, Beachwood, South Toms River, Toms River, and Island Heights.

Methodology

Study Site

Sampling took place every Tuesday at 9:00 AM from May 28 to July 30, 2019 at 8 locations in Pine Beach and Ocean Gate (Figure 1). The Pine Beach sites include Windy Cove, Avon Road, and Station Avenue. The Ocean Gate sites include Jeffrey's Creek, Asbury Avenue, Wildwood Avenue, Stone Harbor Avenue, and Anglesea Avenue. An additional sampling day took place on July 31, 2019 as a comparative data set as a result of high bacteria levels found toward the end of the study.

Procedure

Meteorological conditions were recorded at each site using a Kestrel anemometer to measure average wind speed (mph) and a Barnant thermocouple to measure air temperature (°C) (Figure 2; Figure 3). A YSI 556 probe was used to determine water temperature (°C), dissolved oxygen (%;mg/L), conductance (µS/cm), salinity (ppt), and pH (Figure 4). One water sample was collected at each site using a sampling pole and Nasco Whirl-pak thio-bags to ensure water samples were properly preserved. Additionally, one random duplicate sample was collected each week to ensure accurate bacterial results. Samples were transported in a cooler with ice packs to bring back to the laboratory. At lab, chlorophyll tests were run on water samples using a Turner Designs fluorometer. Because a fluorometer measures chlorophyll relatively, a blank of distilled water was run and recorded first to establish a base value. Using the Easygel Coliscan method, 1 mL of sample water was mixed with 100 mL of Easygel Coliscan solution. This mixture was then poured into pre-treated Petri dishes labeled with the date and site number that corresponded to the water sample. Afterwards, bacteria were incubated at 37 °C for 24 hours. Bacterial colonies were then counted after 24 hours and multiplied by 100 to account for the 100 mL sample. The Easygel Coliscan solution indicates *E. coli* colonies with blue dots, fecal coliform colonies with red dots, and other bacterial colonies with white dots (Figure 5).

Statistical Analysis

An ANOVA test was utilized to determine the relationship among sites and their corresponding bacterial levels. One ANOVA test was run for each type of bacteria (Fecal Coliforms, total Coliforms, and other bacteria). If a significance was determined, a Tukey Post-Hoc test was used (SPSS, GLM analysis) to identify which sites were statistically similar to one another for each type of bacteria. An alpha of 0.05 or less was used for all tests.

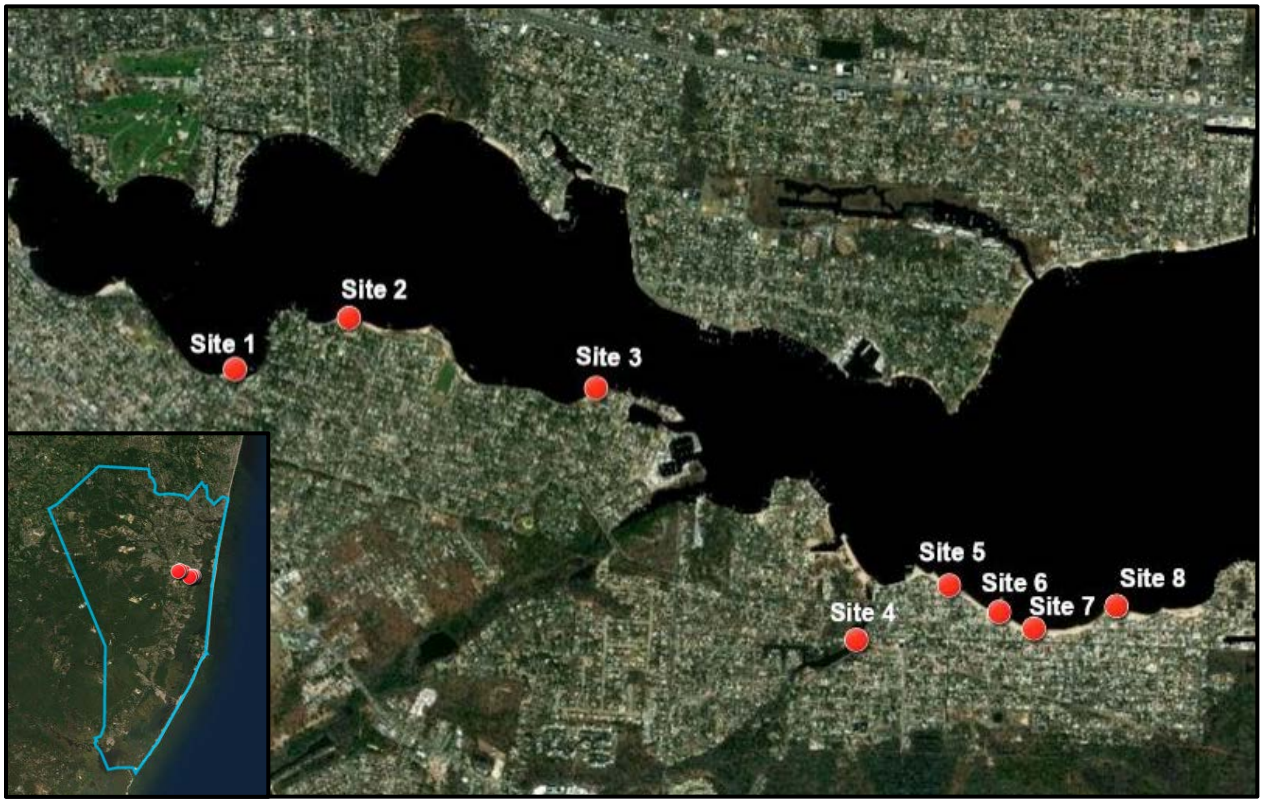

Figure 1: Sampling sites are indicated with red dots and are located along the Toms River, which leads into Barnegat Bay. The first three sites from the left are Windy Cove, Avon Road, and Station Avenue, all located in Pine Beach, NJ. The next five sites, Jeffrey's Creek, Asbury Avenue, Wildwood Avenue, Stone Harbor Avenue, and Anglesea Avenue are located in Ocean Gate, NJ.

Figure 2: A Barnant thermocouple reader was used to record air temperature (°C) at each site.

Figure 3: A Kestrel anemometer was used to record wind speed (mph) at each site.

Figure 4: A YSI 556 probe was used to record water temperature (+/- 0.2°C), dissolved oxygen (%;mg/L), conductance (µS/cm), salinity (ppt), and pH.

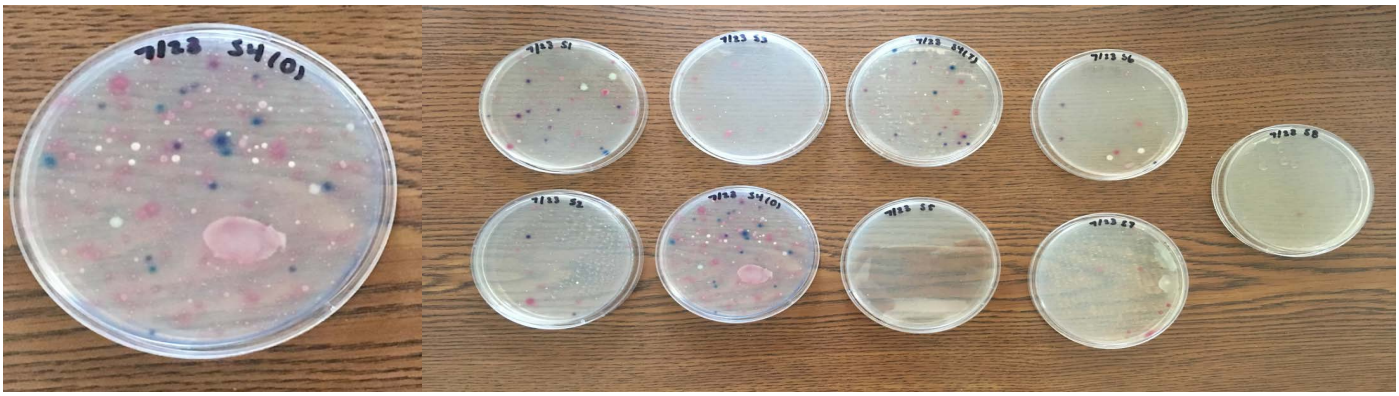

Figure 5: 1 mL of a sample is mixed with Easygel Coliscan solution, poured into Petri dishes, and placed in an incubator at 37 °C. After 24 hours of incubation, bacteria becomes visible in the Petri dishes. Blue dots indicate the presence of E.coli in a sample, red dots indicate fecal coliforms, and white dots indicate other types of bacteria.

Results

Average dissolved oxygen levels ranged from 59.98% or 4.775 mg/L at Site 4 to 96.27% or 7.623 mg/L at Site 3 (Figure 6). Average conductance ranged from 10806.6 uS/cm at Site 1 to 18878.4 uS/cm at Site 8, and consequently average salinity ranged from 6.158 ppt at Site 1 to 11.146 ppt at Site 8 (Figure 7; Figure 8). Average levels of pH ranged from 7.398 at Site 4 to 7.790 at Site 1 (Figure 9). Average chlorophyll-*a* levels ranged from 2.1979 at Site 5 to 4.3256 at Site 4 (Figure 10). Using ANOVA tests, significant differences were determined among Fecal Coliforms, total Coliforms, and other bacteria with p-values of 0.009, 0.011, and 0.044, respectively. Statistically, Fecal Coliform counts were similar among all the sites, excluding Site 4. However, Sites 1 and 2 were also statistically related to Site 4 (Figure 11). For total coliform counts, all of the sites were statistically similar, excluding Site 4 (Figure 12). Additionally, Site 1 was statistically related to Site 4. For other bacteria, Site 5 was statistically unrelated to Site 4 (Figure 13).

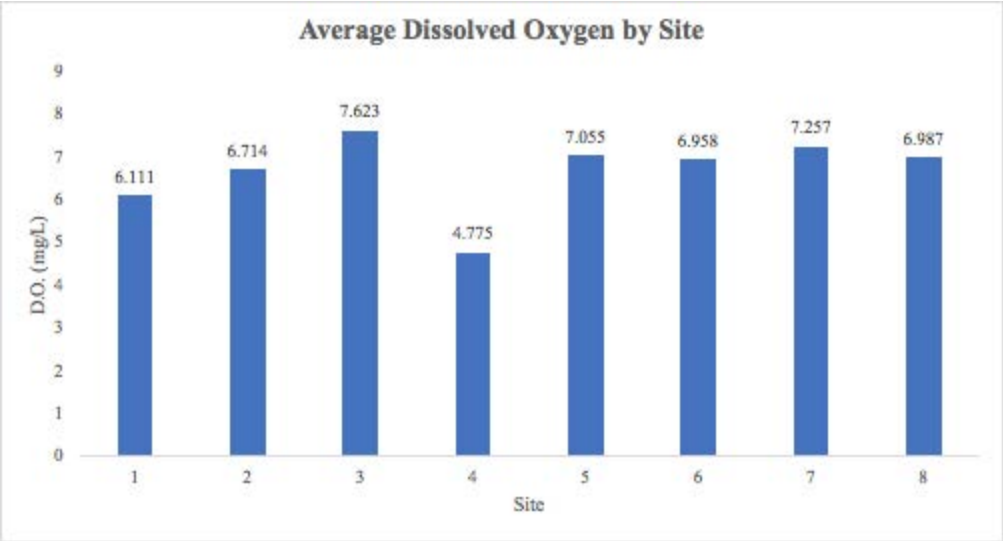

Figure 6: Average dissolved oxygen concentrations (mg/L) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Dissolved concentrations were the lowest at Jeffrey's Creek in Ocean Gate (Site 4) and highest at Station Ave. in Pine Beach (Site 3).

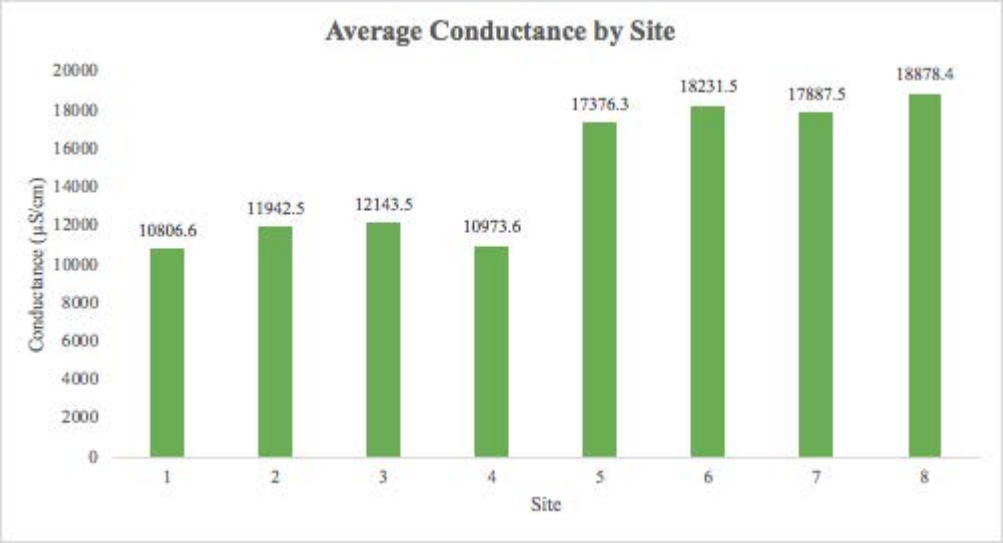

Figure 7: Average conductance (µS/cm) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Conductance jumped from Jeffrey's Creek (Site 4) to Asbury Ave (Site 5) because conductance increases as distance from Barnegat Bay decreases.

Figure 8: Average salinity (ppt) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Salinity jumped from Jeffrey's Creek (Site 4) to Asbury Ave (Site 5) because salinity increases as distance from Barnegat Bay decreases.

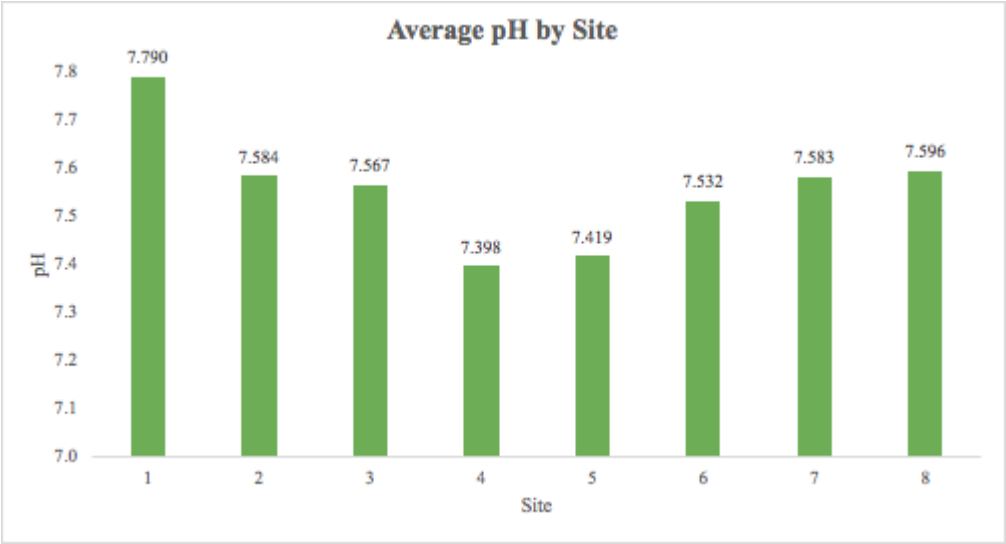

Figure 9: Average pH levels among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Levels of pH were the lowest at Jeffrey's Creek in Ocean Gate (Site 4) and highest at Windy Cove in Pine Beach (Site 1). No values were less than 7.0 throughout testing, therefore the pH axis starts at 7.0.

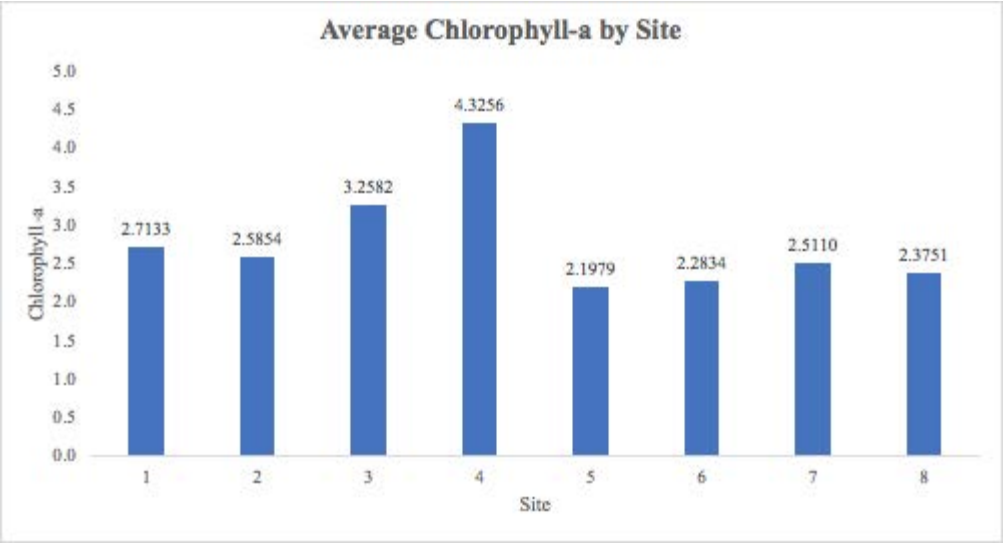

Figure 10: Average relative chlorophyll-a levels among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Chlorophyll-a levels were the lowest at Asbury Ave. in Ocean Gate (Site 5) and highest at Jeffrey's Creek in Ocean Gate (Site 4).

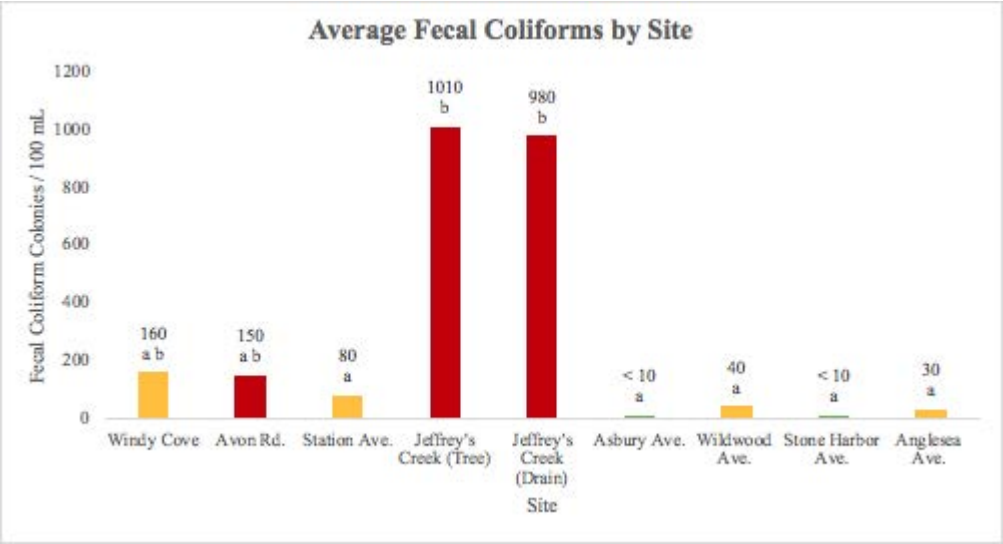

Figure 11: Average Fecal Coliform levels (colonies / 100 mL) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. Red bars indicate highest levels of Fecal Coliforms, yellow bars indicate mid-range levels of Fecal Coliforms, and green bars indicate no detectable levels of Fecal Coliforms. The "a" and "b" designations correspond to the statistical similarity of each site.

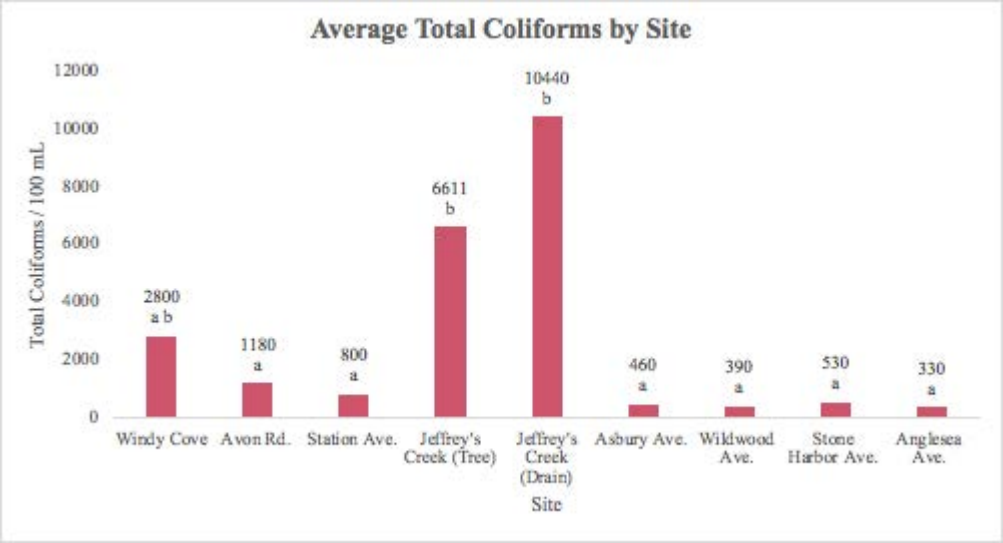

Figure 12: Average Total Coliforms (colonies / 100 mL) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. The "a" and "b" designations correspond to the statistical similarity of each site.

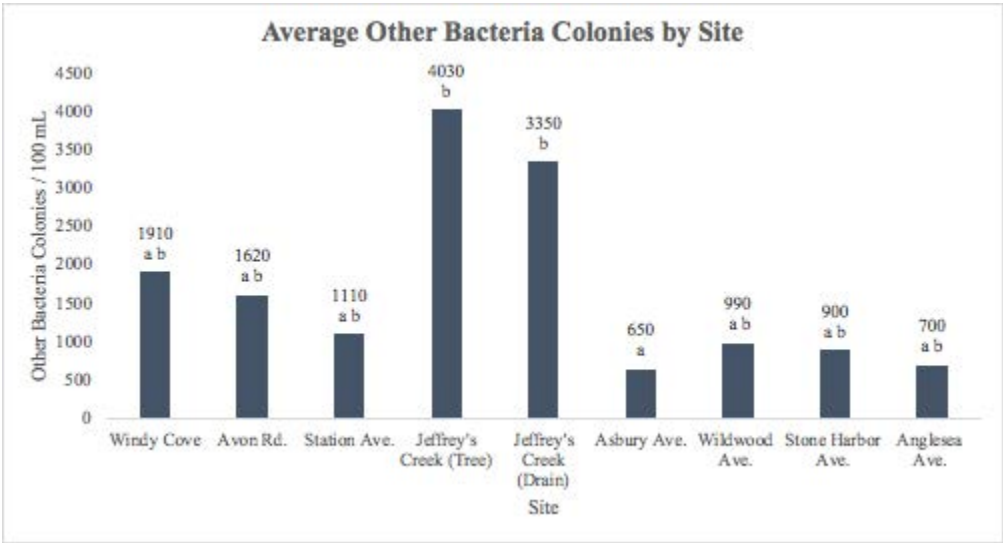

Figure 13: Average other bacteria levels (colonies / 100 mL) among all samples taken over a 10-week period. Samples were collected from 8 locations along Toms River in Pine Beach and Ocean Gate. The "a" and "b" designations correspond to the statistical similarity of each site.

Discussion

Dissolved oxygen levels are the lowest at Site 4 because of its low water flow. As a pond, and therefore a closed system, Site 4 commonly experiences stagnant water, contributing to lower levels of dissolved oxygen. Site 4 was assessed to use as a positive indicator since there was a high presence of waterfowl and it is a closed system that collects runoff between Berkeley Township and Ocean Gate. Average salinity and conductance both ranged from lowest at Site 1 to the highest at Site 8, which is directly related to the salinity gradient of Toms River through Barnegat Bay. As Site 1 is the furthest site from Barnegat Bay, and Site 8 is the closest to Barnegat Bay, salinity and conductance both increase as distance to Barnegat Bay decreases. Levels of pH were lowest at Site 4, which can be related to its relatively high concentration of chlorophyll-a when compared to the other sites. As plant growth and organic material increase in a water body and begin to decompose, pH levels tend to decrease as carbon dioxide is released (Oram, 2014). Additionally, nitrogen fertilizers potentially run into and remain in the pond, leading to lower pH levels and a depletion of oxygen (EPA). Levels of pH are relatively higher at Site 1, which may indicate a lower influence of fertilizers at this location. Additionally, there is a possibility of more organics or tannins since Site 1 is in close proximity to the freshwater inputs from the upper Toms River. However, further sampling would have to be completed in order to investigate the influence of nitrogen fertilizers at each site. Chlorophyll-a concentrations at Site 5 were the lowest, which can be related back to its open system and little organic activity. Additionally, there may be greater flushing at Site 5 because the Toms River becomes significantly wider at this point (Figure 1).

The results of the ANOVA tests indicate a statistical difference among all of the sites for Fecal Coliforms, total Coliforms, and other bacteria ($P<0.05$). A Tukey HSD Post-Hoc test was then performed on each dataset to determine which sites were related to one another. For Fecal Coliforms, all sites excluding Site 4 were statistically similar; however, Sites 1 and 2 were also found to be similar to Site 4 (Figure 11). Based on these results, it is shown that Sites 1 and 2 may experience the water flow of a closed system such as Site 4, as less water movement poses a greater risk of bacterial growth (Rusconi, Guasto and Stocker, 2014). Furthermore, for Total Coliform counts, Site 1 was the only location statistically similar to Site 4; all sites excluding Site 4 were related (Figure 12). At Site 1, an eddy often forms due to currents and wind patterns present. High coliform counts at Site 1 can be attributed to stormwater from Beachwood Beach,

which will be discussed further, getting caught in the eddy. For other bacteria counts, Site 5 was statistically different from Site 4 (Figure 13). Site 5 tested low for all types of bacteria throughout the study, while Site 4 tested high for all types of bacteria throughout the study.

The cleanliness of each site was assessed by counting the amount of times each site surpassed the standard 200 colonies / 100 mL standard for fecal coliforms, which is the EPA standard for fecal coliforms (United States, Environmental, 2012). Site 5 and Site 7 were found to have the cleanest water, not violating the 200 colonies / 100 mL standard. Sites 1, 3, 6, and 8 violated the 200 colonies / 100 mL standard less than 3 times but at least once. Sites 2 and 4 had the worst water quality, having violated the 200 colonies / 100 mL standard more than 3 times (Table 1). Site 5 and Site 7 were suspected to be the cleanest sites because they are open systems, where constant water flow can flush out bacteria (Rusconi et al., 2014). Additionally, as the site locations become closer to the bay, salinity increases. Higher salinity has been shown to inhibit the growth of fecal coliforms, which could also contribute to the cleanliness of Sites 5 and 7 (Stahl et al., 2016). Sites 5 and 7, Asbury Avenue and Stone Harbor Avenue, are the least accessible sites, which could indicate less use and less human activity bringing additional bacteria into the site. Site 2 is among the sites that have the worst water quality. This could be because of its proximity to Site 1, which is downstream from Beachwood Beach (Figure 1). Beachwood Beach is often closed to swimming due to elevated levels of bacteria (Grom, 2018). When water flows out of Beachwood Beach, it is possible that the contaminated water could pass through or even remain at Site 2, leading to Site 2 having poor water quality. Site 4 was also found to have poor water quality. It is suspected that because Site 4 is a pond, and therefore a closed system, the bacteria was not able to be flushed out of the system, and has a longer residence time in the pond than in the other sites. Additionally, there is a high waterfowl presence in the area, leading to more fecal matter that can contaminate the lake with bacteria (USGS).

Table 1: A breakdown of water quality from best to worst by site based on bacterial rating. Ratings are based on the EPA standard of less than 200 colonies per 100 mL for safe swimming water.

Cleanest water: did not violate the 200 colonies / 100 mL standard	Site 5: Asbury Ave.
	Site 7: Stone Harbor Ave.
Middle rating: violated 200 colonies / 100 mL standard < 3 times	Site 1: Windy Cove
	Site 3: Station Ave.
	Site 8: Anglesea Ave.
Worst water quality: violated 200 colonies / 100 mL standard > 3 times	Site 2: Avon Rd.
	Site 4: Jeffrey's Creek

Conclusion

Because of their poor water quality ratings, it is recommended that Avon Road and Jeffrey's Creek should be monitored regularly. Additionally, bacterial levels at Avon Road and Windy Cove should be considered in relation to bacterial levels at Beachwood Beach. Among the sites included in this study, Asbury Avenue and Stone Harbor Avenue, both in Ocean Gate, are the safest locations to swim due to their open systems and proximity to Barnegat Bay.

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