Manhasset Bay
Protection Committee

2023

2016 – 2021 & 2022 Manhasset Bay Water Quality Analyses

Manhasset Bay Protection Committee

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1 Introduction

1.a Background

The Manhasset Bay Protection Committee (henceforth "MBPC") is an inter-municipal organization formed in 1998, focused on addressing water quality and coastal issues in Manhasset Bay with a coordinated, watershed-level approach. The 15 member municipalities are: Nassau County, the Town of North Hempstead, and the villages of Baxter Estates, Flower Hill, Great Neck, Kensington, Kings Point, Manorhaven, Munsey Park, Plandome, Plandome Heights, Plandome Manor, Port Washington North, Sands Point, and Thomaston. More information on the Committee is available at ManhassetBay.net. The Committee's goals are to protect, restore, and enhance Manhasset Bay so as to insure a healthy and diverse marine ecosystem while balancing and maintaining recreational and commercial uses. Tasks that help toward these goals include the annual water quality monitoring and regular assessment of Manhasset Bay.

Manhasset Bay is one of the westernmost estuarine embayments of the north shore of Long Island, NY. The Bay is, therefore, influenced by activities in and around New York City and Long Island Sound, but this report only investigates what is happening within the Bay. According to the New York State Department of Environmental Conservation's (the State regulatory agency concerned with environmental issues both on the land and in the water) Priority Waterbodies List, Manhasset Bay is impaired by pathogens (as indicated by the bacteria fecal coliform and enterococcus) from stormwater runoff, which is the focus of this analysis and report.

Manhasset Bay is broken into three portions (Fig. 1) according to the New York State Department of Environmental Conservation (henceforth NYSDEC) Waterbody Inventory/Priority Waterbodies List. These portions, their descriptions, and other details are summarized in Table 1. Portions 1 and 2 of Manhasset Bay are also on the NYS Section 303(d) List of Impaired Waters Requiring a TMDL[1]or Other Strategy[2]. Portion 1 is listed as a shellfishing restricted impairment for pathogens from urban/stormwater runoff requiring TMDL development. Portion 2 is listed as an individual waterbody segment with pathogen impairment from urban/stormwater runoff requiring TMDL development.

[1] Total Maximum Daily Loads (TMDL) are defined by the EPA as "the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet water quality standards. A TMDL determines a pollutant reduction target and allocates load reductions necessary." From: https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls
[2] June 2020 https://www.dec.ny.gov/docs/water_pdf/section303d2018.pdf; NYS 303(d) webpage: https://www.dec.ny.gov/chemical/31290.html

Table 1. Portions of Manhasset Bay, their class, and their impairments from the 2018 DEC Waterbody Inventory/Priority Waterbodies List[3]

	Class	Known Major pollutant	Source	Portion description
Portion 1	SA[4]	DO/Oxygen Demand, Nutrients, Pathogens	STPs, Urban/stormwater runoff	Bay waters southeast of a line from Hewlett Point to Barker Point, southwest of a line from Plum Point to Port Washington Yacht Club dock, and north of a line running east of Harbor Way dock.
Portion 2	SB[5]	Pathogens	Urban/stormwater runoff	Bay waters northeast of a line from Plum Point to Port Washington Yacht Club dock.
Portion 3	SC[6]	Pathogens	Urban/stormwater runoff	Bay waters south of a line running east from Harbor Way dock.

1.b Report Purpose

The goal of this project is to compile Manhasset Bay bacteriological and water quality data collected during the summers of 2016 through 2021 (Memorial Day to Labor Day), correlate that data with any weather or environmental variables present, and assess the water quality relative to applicable standards. Funding for this report was provided from the New York State Environmental Protection Fund (C00493GG) as administered by the New York State Department of Environmental Conservation. Additionally, the Town of North Hempstead donates Bay Constable time and the boat, gas, etc. used for sampling and the Nassau County Department of Health donates the cost of bacteria analysis, sample bottles, etc. for this sampling program. The monitoring data will be used by the Manhasset Bay Protection Committee, the Nassau County Department of Health, the New York State Department of Environmental Conservation, and the communities surrounding Manhasset Bay.

Graphical and statistical analysis of Manhasset Bay data was performed and used for correlation analysis, along with rainfall data obtained from LaGuardia Airport in order to address the following:

1. How do in-bay bacteria levels compare to NYSDEC ambient water quality standards (NYCRR 6 Part 703.4)?
2. Is there a relationship between counts of the two indicator bacteria species and rainfall?

[3] https://www.dec.ny.gov/chemical/36730.html
[4] The best usages of **Class SA** waters are shellfishing for market purposes, primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish and wildlife propagation and survival.
[5] The best usages of **Class SB** waters are primary and secondary contact recreation and fishing. They shall be suitable for fish, shellfish and wildlife propagation and survival.
[6] The best usage of **Class SC** waters is fishing. These waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

3. How do abiotic factors such as precipitation affect other water quality parameters?
4. Is there a spatial difference in bacteria concentrations within the bay?
5. Is there an interannual difference in bacteria concentrations?

Water quality reports such as this one are important as they set a baseline to compare future progress against, identify sources of water pollution, and set a course of next steps to continue the progress already made.

Figure 1. Nassau County Geographic Information System map of Manhasset Bay and vicinity *(2009) with approximate boundaries for DEC's Waterbody Portions superimposed on top. For general informational purposes only.*

1.c Ambient Water Quality Standards

Section 303(c) of the Clean Water Act (CWA) requires States to develop water quality standards; a process regulated by the US Environmental Protection Agency (EPA) under 40 CFR Part 131[7]. The New York State Department of Environmental Conservation (NYSDEC) recognizes enterococci, total coliform, and fecal coliform as indicators of the possible presence of disease-causing bacteria, viruses, and protozoa (cumulatively referred to as "pathogens"). These "indicator bacteria" are not themselves harmful to humans. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4, these standards are meant to protect human health while recreating:

> Based on summary statistics (geomeans with no more than 10 percent exceedance), the upper value for the density of bacteria for ambient water quality (NYCRR 6 Part 703.4) shall be:

- The monthly geometric mean, from a minimum of five examinations for fecal coliforms, shall not exceed 200 CFU/100 mL for Class SB and SC waters. There is no fecal coliform standard for SA waters.
- For Enterococci the geometric mean of samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL for Class SA and SB waters. There is no Enterococci standard for SC waters.
- NYSDEC also has standards for total coliforms (number per 100 ml), however, MBPC does not test for that and, so, it is not included here.

> New York State recognizes both enterococci and fecal coliform as **indicators** of the presence of disease-causing organisms, though these are not harmful.

Site names, their designated abbreviations, associated portion and class, the applicable bacteria standard, and a description of their relative locations for the seven (7) monitoring stations located in Manhasset Bay are summarized in Table 2. The Nassau County Department of Health, who produces the bacteria counts for MBPC, only analyzes for Fecal coliform and Enterococci, therefore, these are the standards that the water quality data was compared to.

Water quality standards for shellfishing are maintained by NYSDEC's Division of Marine Resources and use a different technique for testing bacteria concentrations. For that reason, these results cannot be used to determine if Bay water is safe for the harvest of shellfish.

NYSDEC has also established ambient water quality standards for dissolved oxygen (DO). The DO standard for all three portions of Manhasset Bay is a daily average of 4.8 mg/L, with allowable excursions to not less than 3.0 mg/L based on a continuous collection of DO measurements over 24 hours.[8] MBPC does not collect continuous dissolved oxygen data, so, strictly speaking, this standard cannot be applied. However, it can be used as a reference point for the data points that are collected.

[7] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-131
[8] November 2008: https://www.dec.ny.gov/docs/water_pdf/togs116.pdf

2 Methodology and Data Collected

2.a Sampling Locations and Background

The water quality monitoring encompasses seven (7) sites (Table 2) spread throughout Manhasset Bay (the Bay tidally exchanges water with Long Island Sound; Fig. 2). These locations were chosen based on the need to get full coverage of the Bay in areas experiencing different stressors. Most of the sampling sites are located along the perimeter of the Bay and, as such, may miss some water quality dynamics of the central Bay, but, given the screening level nature of this monitoring, these sampling locations are sufficient. Additionally, it is anticipated that the largest water quality impacts will be close to shore and, therefore, these sites can serve as a proxy for what is happening in the central Bay[9]. Below follows an accounting of sampling methods by year, but, for a more in-depth accounting, please see the 2016 – 2021 Data Usability Assessment Report available at https://manhassetbayprotectioncommittee.org/water-quality.html.

2.b Sampling Methods

Once per week (Mondays) between Memorial Day and Labor Day[10] of each year, the Town of North Hempstead (henceforth Town) Bay Constables (generally the same two every sampling day for the summer) collected data at seven (7; Fig. 2)[11] disparate sites around Manhasset Bay on the site conditions (air and water temperature, wind speed and direction, weather, and wave height) as well as surface water samples for bacteria counts. The Nassau County Department of Health then analyzed the water samples for *Fecal coliform* and *Enterococci* (CFU/100mL) in their ELAP-certified laboratory according to a QAPP maintained by the New York State Department of Health. The data from these efforts are provided to the MBPC Executive Director (henceforth "Director") in Microsoft Excel[12].

[9] This data is only meant to be representative of what is happening within the Bay during June – August. Therefore, this data is not meant to be representative of conditions outside the Bay nor during winter months.

[10] Memorial Day is the last Monday of May and Labor Day is the first Monday of September, sampling occurred between these dates, but does not include these dates.

[11] This was increased in the summer of 2017; previously only six (6) sites were collected, including the summer of 2016.

[12] PDF versions of this data are available by year (starting in 2009) on the MBPC website at https://manhassetbayprotectioncommittee.org/water-quality.html The Microsoft Excel versions of this data are available by contacting the Director at mbpcExec@gmail.com.

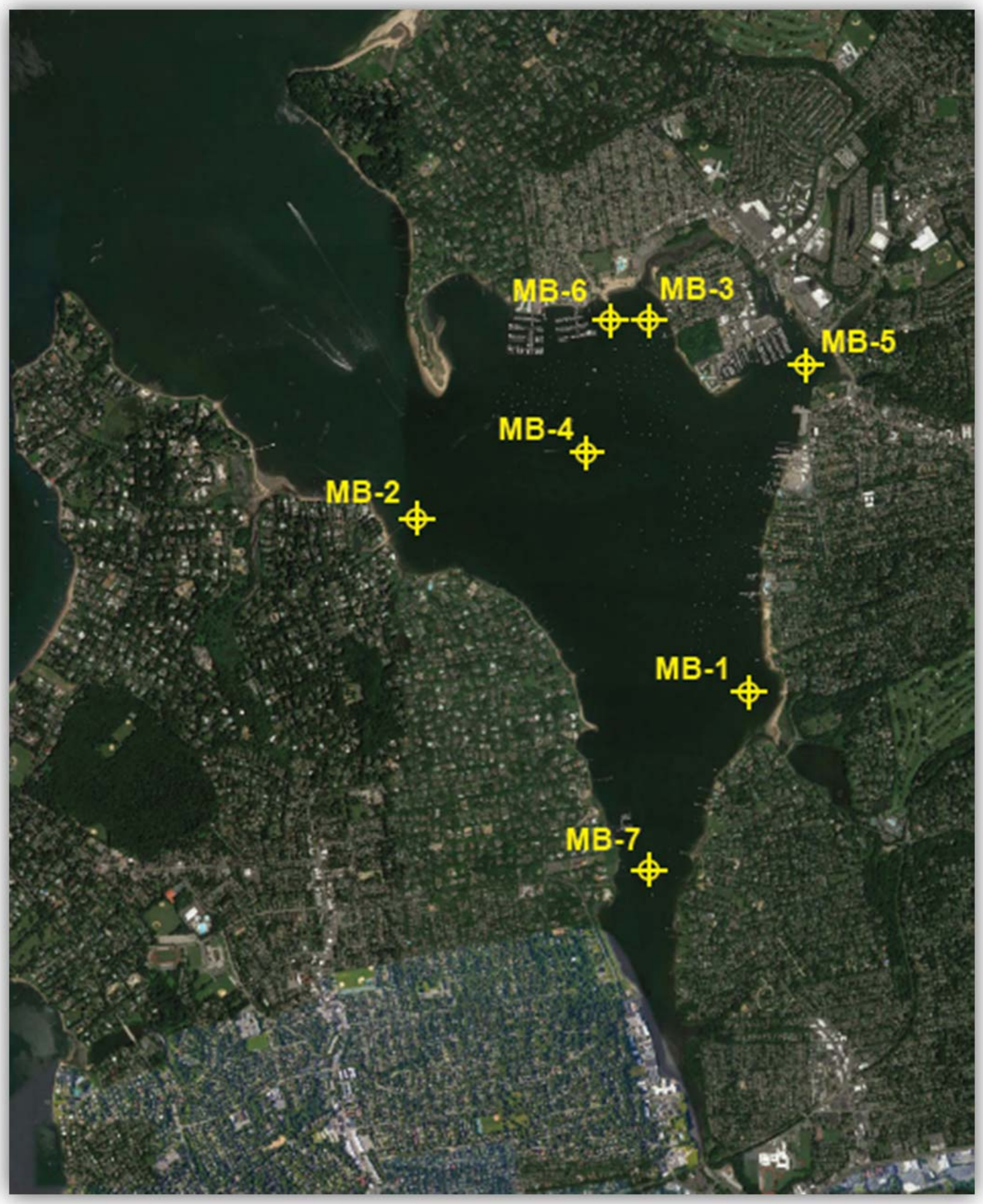


Figure 2. Map of sample locations in Manhasset Bay and their respective abbreviated labels. *Map was produced by D&B Engineers and Architects, P.C. for the Manhasset Bay Protection Committee using the same funding from NYSDEC as this project.*

Table 2. Site names, their designated abbreviations, associated portion and class, the applicable standard, and a description of their relative locations for the seven (7) monitoring stations located in Manhasset Bay

Abbrv.	Site Name	Portion	Class	Fecal Coliforms (# per 100mL)	Enterococci (# per 100mL [CFU or MPN])	Location Description
MB-1	Leeds Pond	1	SA		The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Eastern shore of the Bay near the outlet of one of the major freshwater sources
MB-2	Kennelworth	1	SA		The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Northwestern shore near the mouth; this station experiences a lot of flushing with Long Island Sound
MB-3	Manorhaven	2	SB	The monthly geometric mean from a minimum of five examinations, shall not exceed 200	The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Northern shore near Sheets Creek
MB-4	NUN 4	1	SA		The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Aide to navigation buoy in the central channel of the Bay. Likely experiences a lot of flushing.
MB-5	Baxter Beach	2	SB	The monthly geometric mean from a minimum of five examinations, shall not exceed 200	The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Northeastern shore near a lot of development and the outfall for the Port Washington WPCD
MB-6	Manorhaven Beach	2	SB	The monthly geometric mean from a minimum of five examinations, shall not exceed 200	The monthly geometric mean of samples collected over any consecutive 30-day period shall not exceed 35, and no more than 10% of the samples in the same 30-day period shall exceed 130.	Northern shore near a Town recreational facility
MB-7	Great Neck[13]	3	SC	The monthly geometric mean from a minimum of five examinations, shall not exceed 200		Southern area where the Bay gets shallow and more exposed to freshwater inputs. Site is near the outfall for the Great Neck WPCD; as tidal stage allows.

[13] This station was not sampled in 2016. Sampling of this station began in 2017.

For the summer of 2017, the MBPC was successful in securing an equipment loan from the US Environmental Protection Agency's Region 2 Equipment Loan Program. This equipment, known as a YSI Handheld Multiparameter probe (Fig. 3), displays data (temperature, dissolved oxygen, pH, and salinity) on a handheld meter when the probe is lowered into the water column (the two are attached by a cable). These measurements were taken at the surface (approximately one foot depth to top of probe). This equipment added much more diverse data collection, without much more effort. Adding this information was in direct response to a recommendation of the 2017 Water Quality Report produced for the MBPC by Fuss & O'Neill. Summer 2017 also saw the beginning of the MBPC collecting secchi disk (pronounced *seckky*) depths at each station. The 78-010 Fieldmaster Secchi Disk is a weighted 200 mm diameter plastic disk with two white quadrants and two black quadrants. It is lowered into the water column until it can no longer be seen by the observer. This depth gives a relative measure of turbidity (i.e., how much material (e.g., dirt, algae, etc.) is suspended in the water column so that it limits sunlight reaching the bottom), which is important to note, because marine plants and algae need sunlight to grow. The parameters that were analyzed and the sampling methodology are given in Table 3.

Figure 3. Photo of the YSI ProDSS handheld, probe, and cable.

Sampling information for each year is listed below:

- 2016: June through August, 12 sampling events at 6 sampling locations
- 2017: June through August, 13 sampling events at 7 sampling locations
- 2018: June through August, 13 sampling events at 7 sampling locations
- 2019: June through August, 13 sampling events at 7 sampling locations
- 2020: June through August, 10 sampling events at 7 sampling locations
- 2021: June through August, 13 sampling events at 7 sampling locations

Table 3. Summary of Water Quality Parameters and Sampling Methodology

Parameter	Sampling Methodology Description
Temperature Salinity Dissolved Oxygen pH GPS Coordinates	YSI 556-01 MPS (2017) YSI ProDSS (2019)
Enterococci	Membrane Filter, EPA 1600
Fecal coliform	Membrane Filter, SM 9222 D-2006
Water Clarity	Secchi Disk
Water Depth	Onboard depth sounder

2.b.i Summer of 2016

Sampling was performed once per week on Monday mornings from June 2016 through August 2016 at six (6) locations around the Bay by Town Bay Constables. Bacteria samples were collected using a simple dip method at the surface. Depth was determined using a depth sounder on the boat, when available. Site conditions and other information were recorded on a chain of custody data sheet and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets are provided by, transcribed by, and maintained by the Nassau County Department of Health. Every morning after sampling, Nassau County Department of Health personnel collected the refrigerated bacteria samples (and chain of custody forms) from Town Dock and performed the analysis at their ELAP-certified lab. Data is supplied to the Executive Director in Microsoft Excel. Water depth, secchi depth, dissolved oxygen, conductivity/salinity, and pH were not collected in 2016. Additionally, sampling was not done the week of July 4th, due to the holiday.

2.b.ii Summer of 2017

Sampling was performed once per week on Monday mornings from June 2017 through August 2017 at seven (7) locations around the Bay by Town Bay Constables. Sampling was performed as it was in 2016, with the addition of: temperature, dissolved oxygen, pH, and salinity readings taken at the surface (approximately one foot depth to top of probe) using a YSI 556-01 MPS multiparameter probe and turbidity measurements taken via secchi disk with half-meter markings on the line (Appendix B). The YSI multiparameter probe was calibrated before every sampling at Town Dock. Bacteria samples were collected using a simple dip method at the surface. Data measurements, site conditions, and other information were recorded on chain of custody data sheets and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets are provided by, transcribed by, and maintained by the Nassau County Department of Health. Duplicate measurements were taken at one station chosen at random per sampling event. Typically, two bay constables performed the sampling; the MBPC Director participated in sampling at least once per month for Quality Assurance purposes. The Committee maintains and provided Bay Constables with SOPs for the operation of the YSI. YSI data was entered into Microsoft Excel by the Director. All parameters were sampled in 2017, except for during the first three (3) weeks.

2.b.iii Summer of 2018

Sampling was performed once per week on Monday mornings from June 2018 through August 2018 at seven (7) locations around the Bay by Town Bay Constables. Sampling was performed as it was in 2016, with the addition of: turbidity measurements taken via secchi disk with half-meter markings on the line (Appendix B). The YSI multiparameter probe equipment loan from the EPA was not pursued for a second year in a row as the MBPC decided to purchase a dedicated newer, more advanced YSI probe, but this instrument was not available until the end of the sampling season. A few sampling dates in August were done with the YSI, but this data is not included as it does not offer a useful data record. No data was collected for dissolved oxygen, conductivity/salinity, and pH in 2018. Additionally, no QA measurements were taken for water depth and secchi depth.

Data measurements, site conditions, and other information were recorded on chain of custody data sheets and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets are provided by, transcribed by, and maintained by the Nassau County Department of Health.

2.b.iv Summer of 2019

Sampling was performed once per week on Monday mornings from June 2019 through August 2019 at seven (7) locations around the Bay by Town Bay Constables and the Committee's summer intern. Sampling was performed as it was in 2016, with the addition of: GPS coordinates, temperature, dissolved oxygen, pH, and salinity readings taken at the surface (approximately one foot depth to top of probe) using the MBPC's new YSI ProDSS (Professional Digital Sampling System) Multiparameter probe and turbidity measurements taken via 78-010 Fieldmaster Secchi Disk with half-meter markings on the line (Appendix B). The YSI multiparameter probe was calibrated before every sampling at Town Dock. The Committee maintains and provided the intern and Bay Constables with SOPs for the operation of the YSI. This was the first summer the intern joined sampling. Data was downloaded by the intern using Xylem's Korr software. Water depth was collected via a sounder onboard the boat, which wasn't always working.

Data measurements, site conditions, date, time, and other information were recorded on chain of custody data sheets and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets are provided by, transcribed by, and maintained by the Nassau County Department of Health.

2.b.v Summer of 2020

Summer 2020 saw the full impact of the Novel Coronavirus pandemic. Sampling was scaled back in that YSI readings were not performed in order to keep sampling staff levels at a minimum to control the spread of the virus. Additionally, the start of sampling was delayed until the end of June.

Sampling was performed once per week on Monday mornings from June 2020 through August 2020 at seven (7) locations around the Bay by Town Bay Constables. Sampling was performed as it was in 2016. Site conditions, date, time, and other information were recorded on chain of custody data sheets and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets were provided by, transcribed by, and maintained by the Nassau County Department of Health. Turbidity measurements were taken via secchi disk with half-meter markings on the line (Appendix B).

Secchi disk depths from 2020 are not used in this report. Unfortunately, quality assurance (QA) measurements were not done this year. That combined with the limited number of measurements (only five) made it impractical to analyze these data points.

2.b.vi Summer of 2021

Summer 2021 still saw the lingering impact of the Novel Coronavirus pandemic. Sampling was scaled back in that YSI readings AND secchi depths were not performed in order to keep sampling staff levels at a minimum to control the spread of the virus.

Sampling was performed once per week on Monday mornings from June 2021 through August 2021 at seven (7) locations around the Bay by Town Bay Constables. Sampling was performed as it was in 2016. Site conditions, date, time, and other information were recorded on chain of custody data sheets and labeled with the Station ID (MB-1, -2, etc; Appendix A). These chain of custody sheets are provided by, transcribed by, and maintained by the Nassau County Department of Health.

2.c Additional Data Sources

Local weather (specifically precipitation) was collected from external sources for this report (Appendix C). Precipitation data from LaGuardia Airport, the closest weather station, was gathered from the NOAA National Centers for Environmental Information (NCEI) data request website, which was accessed from https://www.ncdc.noaa.gov/cdo-web/datatools/lcd.

2.d Data Limitations

Manhasset Bay experiences a large tidal range and some portions of the Bay are getting shallower. As such, some sites are not accessible during sampling, since sampling is set on a fixed schedule (Monday mornings, except holidays, through the summer). Samplers made every attempt to get as close to the sampling location as possible and took their GPS coordinates. Tidal stage had the biggest impact on sampling at the Great Neck (MB-7) site, but also affected the Baxter Beach (MB-5) and Leeds Pond (MB-1) sites.

Daily weather data for this report was acquired from the NOAA Weather Station at LaGuardia airport (this is made available in both tab-delimited format and pdf). In the raw data set, a “T” denotes a rainfall amount that is “Trace” (not measurable, < 0.01"). Since this is nominal, all “T”s in the data set were made “0.” There are some additional limitations for this data: given time constraints, only daily weather logs were used, forcing the assumption that all rainfall the day-of sampling occurs prior to the sampling. Additionally, this weather data was used as representative of the whole Bay, which is not true.

Since water quality parameters were collected inconsistently from year-to-year, this data cannot be compared over the course of years, but only within each sampling season.

2.e Data Analysis

All data storage and analysis is in Microsoft Excel.

2.f Other Observations and Activities on the Bay

2.f.i Rust-colored water

On a few sampling dates in 2017, the Bay Constables reported the water was a rust color (Fig. 4). The NYSDEC Division of Marine Resources samples the Bay on a rotating basis for fish counts and was able to collect a water sample for analysis on the morning of June 28, 2017. The dominant phytoplankton[14] species was identified as the non-harmful *Heterocapsa* by Dr. Theresa Hattenrath, formerly at Stony Brook University. However, as this was a single sample taken on a single day, it is impossible to say for sure if this was the cause of the rust color observed in the Bay.

Figure 4. Photo of Manhasset Bay on July 12, 2017 from Town Dock, Port Washington, NY showing a slight brown tinge to the water.

[14] Phytoplankton are a plant-like, single-celled organism, which are vital to marine ecosystems. Some species, when in abundance, are known to cause harmful effects.

3 Results

In this report correlations between data points will be highlighted, however, a correlation does not necessarily mean causation. This report cannot specifically identify trends, since trends cannot be detected on such a short time-scale. However, the report will compare bacteria data over the years sampled, but any inferences made do not necessarily mean there is a trend.

Note that the Nassau County Department of Health used a value of 0.1 CFU/100 ml for zero values of bacteria to allow log-based calculations. Those values were retained and used for all analyses.

3.a Bacteria Levels v. Ambient Water Quality Standards.

Bacteria data (Appendix A) was compared to the NYSDEC ambient water quality standards by station (Appendix D).

3.a.i Leeds Pond (MB-1)

The Leeds Pond station is located in Portion 1 of Manhasset Bay, which is classified as SA waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for class SA waters: "the geometric mean of Enterococci samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL." Considering that:

- More than 10% of the samples in the same 30-day period exceeded 130 CFU of Enterococci in 2016 and the monthly geometric mean of samples collected over a consecutive 30-day period exceeded 35 CFU of Enterococci on two occasions. Sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer of 2016.
- More than 10% of the samples in the same 30-day period exceeded 130 CFU of Enterococci in 2018. However, the 2018 monthly geometric means of samples collected over any consecutive 30-day period never exceeded 35 CFU of Enterococci.
- Samples never exceeded the single-sample nor rolling- geometric mean standard for Enterococci in 2017, 2019, or 2020.
- More than 10% of the 2021samples in the same 30-day period exceeded 130 CFU of Enterococci and the monthly geometric mean of samples collected over a consecutive 30-day period exceeded 35 CFU of Enterococci on several occasions.

3.a.ii Kennelworth (MB-2)

The Kennelworth station is located in Portion 1 of Manhasset Bay, which is classified as SA waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for class SA waters: "the geometric mean of Enterococci samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL." Considering that, at Kennelworth:

- More than 10% of the samples in the same 30-day period exceeded 130 CFU of Enterococci in 2016. However, the 2016 monthly geometric means of samples collected over any consecutive

30-day period never exceeded 35 CFU of Enterococci. Sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer of 2016.

- Samples never exceeded the single-sample nor rolling- geometric mean standard for Enterococci in 2017, 2018, 2019, or 2020.
- More than 10% of the 2021samples in the same 30-day period exceeded 130 CFU of Enterococci and the monthly geometric mean of samples collected over a consecutive 30-day period exceeded 35 CFU of Enterococci on one occasion.

3.a.iii Manorhaven (MB-3)

The Manorhaven station is located in Portion 2 of Manhasset Bay, which is classified as SB waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for SB waters:

- *"The monthly geometric mean, from a minimum of five examinations for fecal coliforms, shall not exceed 200 CFU/100 mL.*
- *"For Enterococci the geometric mean of samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL."*

For the Manorhaven site:

- Samples never exceeded the single-sample nor rolling- geometric mean standard for Enterococci or Fecal coliform in 2016, 2017, 2018, 2019, or 2020. Sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer.
- 2021 samples never exceeded the rolling monthly geometric mean standard for Enterococci or Fecal coliform. However, more than 10% of the 2021samples in the same 30-day period exceeded 130 CFU of Enterococci.

3.a.iv NUN 4 (MB-4)

The NUN 4 station is located in Portion 1 of Manhasset Bay, which is classified as SA waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for class SA waters: "the geometric mean of Enterococci samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL." Considering that, for the NUN-4 site:

- Samples never exceeded the single-sample nor rolling- geometric mean standard for Enterococci in 2016, 2017, 2018, 2019, or 2020. Sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer.
- 2021 samples never exceeded the rolling monthly geometric mean standard for Enterococci. However, more than 10% of the 2021samples in the same 30-day period exceeded 130 CFU of Enterococci.

3.a.v Baxter Beach (MB-5)

The Baxter Beach station is located in Portion 2 of Manhasset Bay, which is classified as SB waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for SB waters:

- *"The monthly geometric mean, from a minimum of five examinations for fecal coliforms, shall not exceed 200 CFU/100 mL.*

- *"For Enterococci the geometric mean of samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL."*

Considering that, at Baxter Beach:

- No standards were exceeded in 2016 or 2017. However, sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer of 2016.
- The 2018 and 2019 monthly geometric means from a minimum of five examinations, never exceeded 200 CFU of Fecal Coliform, nor 35 CFU of Enterococci. However, more than 10% of samples collected in a rolling 30-day period exceeded 130 CFU of Enterococci (on two occasions in 2018 (6/4 and 7/23) and on 6/24/2019).
- More than 60% of the 2020 and 2021 monthly geometric means from a minimum of five examinations exceeded 200 CFU of Fecal Coliform. Half of the 2020 and one-third of the 2021 monthly geometric means from a minimum of five examinations exceeded 35 CFU of Enterococci. More than 10% of samples collected in a rolling 30-day period exceeded 130 CFU of Enterococci in 2020 and 2021.

3.a.vi Manorhaven Beach (MB-6)

The Manorhaven Beach station is located in Portion 2 of Manhasset Bay, which is classified as SB waters. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4 for SB waters:

- *"The monthly geometric mean, from a minimum of five examinations for fecal coliforms, shall not exceed 200 CFU/100 mL.*

- *"For Enterococci the geometric mean of samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL (or MPN) and no more than 10 percent of the samples collected in the same 30-day period shall exceed 130 CFU/100 mL."*

Considering that, at Manorhaven Beach:

- The 2016, 2017, and 2018 monthly geometric means from a minimum of five examinations, never exceeded 200 CFU of Fecal Coliform, nor 35 CFU of Enterococci. However, more than 10% of samples collected in a rolling 30-day period exceeded 130 CFU of Enterococci in all three years. Sampling was skipped on 7/4/2016 making it impossible to do 30-day geometric means for samples collected earlier in the summer.

- In 2019, data is missing for 7/29/2019, so rolling 30-day geometric mean standards can only be assessed for the sampling dates before. These rolling geometric means never exceeded the Fecal coliform nor Enterococci standards. Additionally, no samples collected in a rolling 30-day period exceeded 130 CFU of Enterococci, though the 7/29 data point remains unknown.
- Samples never exceeded the single-sample nor rolling- geometric mean standard for Enterococci or Fecal coliform in 2020.
- The 2021 monthly geometric mean from a minimum of five examinations never exceeded 200 CFU of Fecal Coliform. However, more than 10% of samples collected in a rolling 30-day period exceeded 130 CFU of Enterococci and the monthly geometric mean from a minimum of five examinations exceeded the 35 CFU of Enterococci on two occasions.

3.a.vii Great Neck (MB-7)

The Great Neck station is located in Portion 3 of Manhasset Bay, which is classified as SC waters. Note that this station was not sampled in 2016. NYSDEC Division of Water has set the following recreational ambient water quality standards as identified in NYCRR 6 Part 703.4: "the monthly geometric mean, from a minimum of five examinations for fecal coliforms, shall not exceed 200 CFU/100 mL." Considering this, at the Great Neck site:

- Great Neck was not sampled in 2016.
- The 2017, 2018, 2019, and 2021 monthly geometric means from a minimum of five examinations never exceeded 200 CFU of Fecal Coliform.
- More than 30% of the 2020 monthly geometric means from a minimum of five examinations exceeded 200 CFU of Fecal Coliform.

3.b Is There a Relationship Between Counts of the Two Indicator Bacteria Species and Rainfall?

Statistical and graphical analysis was used to determine relationships (correlations) between concentrations of indicator bacteria organisms and rainfall. Tables of correlations between bacteria concentrations and rainfall are provided in Tables 4 through 9 below. Note that the Nassau County Department of Health used a value of 0.1 CFU/100 ml for zero values of bacteria, presumably to allow log-based calculations. Those values were retained and used for all analyses.

Daily weather data for this report was acquired from the NOAA Weather Station at LaGuardia airport (this is made available in both tab-delimited format and pdf; summary spreadsheets of data can be found in Appendix C). In the raw data set, a "T" denotes a rainfall amount that is "Trace" (not measurable, < 0.01"). Since this is nominal, all "T"s in the data set were made "0." There are some additional limitations for this data. Given time constraints, only daily weather logs were used, forcing the assumption that all rainfall the day-of sampling occurs prior to the sampling.

The Pearson Correlation calculates an *r*-value between -1 and +1 in order to determine if and how strong a relationship is between two variables (an *r*-value of zero means that there is no relationship). If the coefficient is positive, then the two variables tend to increase together. If the coefficient is negative, one variable tends to decrease as the other variable increases. As positive *r*-values approach "+1," the two variables are more closely related (a value of +1 indicates a perfect correlation), therefore *r-values* equal to and higher than 0.70 are significant. No *r*-values less than zero generated for these data sets were significant (*r* > -0.70). Untransformed bacteria data was used for these calculations. As always, correlations do not necessarily mean causation, however, the premise (based on watershed models) of the MS4 and other programs is that rainfall affects bacteria counts in the Bay for up to two (2) days. This test was chosen as it was the same test performed for the last water quality analysis.

3.b.i Summer of 2016 - Bacteria v. Rainfall

The Pearson Correlation Coefficient performed for 2016 precipitation data demonstrated a strong correlation (*r > 0.70*) at all stations between bacteria counts of both species with rainfall that occurred the day prior. There was no correlation shown between bacteria counts and rainfall either the day-of or two-days prior (Table 4). This would mean that rain was a factor for June 6, August 1, and August 22 during the summer of 2016, which would account for all of the exceedances in 2016 at all sites.

Table 4. Pearson correlations for 2016 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. Significant findings are highlighted.

2016	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	0.42	0.37	0.73	0.93	-0.14	-0.06
MB-2	0.45	0.31	0.83	0.73	-0.16	-0.19
MB-3	0.42	0.41	0.73	0.73	-0.13	-0.07
MB-4	0.42	0.44	0.73	0.74	-0.13	-0.13
MB-5	0.42	0.49	0.75	0.87	-0.14	-0.16
MB-6	0.42	0.44	0.73	0.87	-0.13	-0.03

3.b.ii Summer of 2017 - Bacteria v. Rainfall

The Pearson Correlation Coefficient performed for 2017 precipitation data yielded the following results (Table 5):

- Bacteria counts at station MB-1 do not show any correlation (*r < 0.70*) with rainfall within the two days of sampling (this was confirmed with a linear regression, not shown).[15]
- At station MB-2, higher counts of *Fecal coliform* correlate with rainfall two-days prior (*r = 0.91*)[16]. At this same station, higher counts of *Enterococci* correlate with a rainfall the day before a sampling (*r = 0.826*). However, there are no exceedances at this site in 2017.
- Bacteria counts at station MB-3 do not show any correlation (*r < 0.70*) with rainfall within the two days of sampling (this was confirmed with a linear regression, not shown).[17]
- Counts of *Enterococci* at MB-4 correlate (*r = 0.71*) with rainfall one day prior.[18]

[15] There were no exceedances for MB-1 in 2017.
[16] There were no exceedances for MB-2 in 2017.
[17] There were no exceedances for MB-3 in 2017.
[18] There were no exceedances for MB-4 in 2017.

- For MB-5[19], increases in both indicator bacteria correlate ($r < 0.70$) with rainfall one day prior. Counts of *Fecal coliform* at MB-5 also show a correlation with rainfall the same day as sampling ($r = 0.71$). There were no exceedances at this site in 2017.
- At station MB -6, increases in both indicator bacteria correlate ($r < 0.80$) with rainfall one day prior. This would account for the standard exceedance at MB-6 in 2017.
- For MB-7, *Fecal coliform* counts correlate with rainfall two-days before ($r = 0.70$) and the day-of ($r = 0.87$) sampling. Additionally, *Enterococci* counts at this station show a strong correlation with rainfall the day before sampling ($r = 0.98$).[20]

Table 5. Pearson correlations for 2017 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. Significant findings are highlighted.

2017	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	0.391	0.219	-0.250	0.539	-0.038	0.588
MB-2	0.911	-0.005	0.072	0.826	0.460	0.256
MB-3	0.386	-0.193	0.088	0.446	0.378	-0.093
MB-4	0.185	-0.092	0.636	0.708	0.249	0.130
MB-5	0.361	0.149	0.725	0.888	0.714	0.552
MB-6	0.210	0.179	0.878	0.919	0.556	0.543
MB-7	0.702	0.200	0.633	0.977	0.871	0.559

3.b.iii Summer of 2018 - Bacteria v. Rainfall

The Pearson Correlation Coefficient performed for 2018 precipitation data demonstrated a strong correlation ($r > 0.70$) at all stations except Great Neck (MB-7) between *Fecal coliform* counts with rainfall that occurred the day prior. At Baxter Beach (MB-5), *Enterococci* counts also demonstrated a correlation with rainfall that occurred the day prior. There was no correlation shown between bacteria counts and rainfall either the day-of or two-days prior (Table 6). Considering this, rainfall seems to be a factor in Baxter Beach (MB-5) *Enterococci* exceedances, but not for Leeds Pond (MB-1) or Manorhaven Beach (MB-6; Table 6).

[19] There were no exceedances for MB-5 in 2017.
[20] There were no exceedances for MB-7 in 2017.

Table 6. Pearson correlations for 2018 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. Significant findings are highlighted.

2018	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	0.26	0.09	0.77	0.69	-0.18	0.16
MB-2	0.13	0.53	0.86	0.26	0.01	0.59
MB-3	0.22	0.02	0.84	0.43	0.09	0.53
MB-4	0.13	-0.01	0.97	0.30	0.09	0.56
MB-5	0.02	0.00	0.83	0.76	-0.20	0.20
MB-6	0.10	-0.08	0.90	0.43	0.11	0.46
MB-7	0.42	-0.14	0.27	0.22	0.04	0.43

3.b.iv Summer of 2019 - Bacteria v. Rainfall

In 2019, there was no correlation between rainfall for any of the three scenarios (2-day prior, 1-day prior, and day-of) and either bacteria species (Table 7). There was one exceedance in 2019: at Baxter Beach (MB-5) in late June the statistical threshold value (STV) for Enterococci was exceeded.

Table 7. Pearson correlations for 2019 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling.

2019	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	-0.09	-0.27	0.06	0.10	0.25	-0.28
MB-2	0.08	0.09	-0.13	0.11	-0.27	-0.36
MB-3	0.17	-0.08	0.14	-0.07	-0.13	0.53
MB-4	-0.12	-0.03	0.20	-0.12	0.20	0.04
MB-5	-0.03	-0.14	0.25	0.08	-0.15	-0.17
MB-6	0.59	0.06	-0.12	-0.22	0.19	0.72
MB-7	0.55	0.16	0.33	0.34	-0.05	-0.03

3.b.v Summer of 2020 - Bacteria v. Rainfall

The Pearson Correlation Coefficient performed for 2020 precipitation data yielded the following results (Table 8):

- There was no correlation between rainfall for any of the three scenarios (2-day prior, 1-day prior, and day-of) and either bacteria species at NUN-4 (MB-4), Manorhaven Beach (MB-6), or Great Neck (MB-7). There were no exceedances in 2020 at NUN-4 (MB-4) or Manorhaven Beach (MB-6). However, the *Fecal coliform* geometric mean standard for Great Neck (MB-7) was exceeded twice: July 27th and August 3rd. As such, these cannot be attributed to rainfall.

- At Leeds Pond (MB-1), counts of *Enterococci* showed a correlation (*r >0.7*) for rainfall that occurred one-day prior to sampling.
- At Kennelworth (MB-2), *Fecal coliform* counts showed a correlation (*r >0.7*) for rainfall that occurred two-days prior to sampling. At this same station, counts of *Enterococci* showed a correlation (*r >0.7*) for rainfall that occurred both one-day prior to and on the day-of sampling.
- At the Manorhaven site (MB-3), *Fecal coliform* counts showed a correlation (*r >0.7*) for rainfall that occurred two-days prior to sampling.
- At Baxter Beach (MB-5), *Fecal coliform* counts showed a correlation (*r >0.7*) for rainfall that occurred both one-day prior to and on the day-of sampling. However, there was no correlation between rainfall and *Enterococci* counts. This site had multiple exceedances during the summer of 2020 for which rainfall cannot be a factor.

Table 8. Pearson correlations for 2020 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. Significant findings are highlighted.

2020	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	0.02	-0.14	0.61	0.72	0.20	0.41
MB-2	0.80	0.44	0.51	0.74	0.40	0.70
MB-3	0.75	0.07	0.13	0.19	-0.26	-0.23
MB-4	0.10	0.09	0.21	0.22	-0.21	-0.17
MB-5	-0.17	0.01	0.78	0.18	0.73	-0.12
MB-6	-0.34	-0.36	0.60	0.26	0.58	0.31
MB-7	-0.15	-0.16	-0.16	-0.16	-0.12	-0.11

3.b.vi Summer of 2021 - Bacteria v. Rainfall

The Pearson Correlation Coefficient performed for 2021 precipitation data (Table 9) demonstrated a strong correlation (*r > 0.70*) at all stations between *Fecal coliform* counts with rainfall that occurred the day of. Similarly, the Pearson Correlation Coefficient performed for 2021 precipitation data demonstrated a strong correlation (*r > 0.70*) at all stations except Baxter Estates (MB-5) between *Enterococci* counts with rainfall that occurred the day of (Table 9). These correlations could account for the standard exceedances at Leeds Pond (MB-1), Kennelworth (MB-2), Manorhaven (MB-3), NUN-4 (MB-4). In regards to the other two rainfall scenarios:

- For stations MB-1, MB-2, MB-3, and MB-4, there was no correlation between either bacteria species and rainfall either 1- or 2-days prior to sampling.
- Baxter Estates (MB-5) demonstrated a strong correlation (*r >0.8*) for *Fecal coliform* and rainfall that occurred the day before sampling. Taken with the above, this may account for all the exceedances of the *Fecal coliform* standard at this site.
- Manorhaven Beach (MB-6) had a correlation (*r >0.7*) for *Fecal coliform* and rainfall that occurred two-days and one-day before sampling. Similarly, there was a correlation (*r >0.7*)

between *Enterococci* counts and rainfall that occurred the day before sampling. Taken with the above, this may account for all the exceedances of the *Enterococci* standard at this site in 2021. There were no exceedances of the *Fecal coliform* standard at this site in 2021.

- Great Neck (MB-7) showed a correlation ($r > 0.7$) between *Enterococci* counts and rainfall that occurred the day before sampling. There were no exceedances at this site in 2021.

Table 9. Pearson correlations for 2021 bacteria data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. Significant findings are highlighted.

2021	Two-days prior		One-day prior		Day-of	
	Fecal Coliform	***Enterococci***	***Fecal Coliform***	***Enterococci***	***Fecal Coliform***	***Enterococci***
MB-1	-0.01	-0.05	0.23	0.19	0.87	0.84
MB-2	-0.09	-0.10	0.15	0.14	0.82	0.82
MB-3	0.05	-0.02	0.29	0.22	0.90	0.86
MB-4	-0.09	-0.10	0.14	0.14	0.83	0.82
MB-5	0.67	0.12	0.85	0.39	0.85	0.49
MB-6	0.75	0.65	0.93	0.86	0.79	0.85
MB-7	0.53	0.42	0.77	0.67	0.90	0.92

3.b.vii Annual Rainfall Comparison

Daily weather data for this report was acquired from the NOAA Weather Station at LaGuardia airport. In the raw data set, a "T" denotes a rainfall amount that is "Trace" (not measurable, < 0.01"). Since this is nominal, all "T"s in the data set were made "0."

A t-test calculates a p-value in order to determine if there is a significant difference between two sets of data which cannot be explained by chance. A p-value equal to or less than 0.05 was used as the threshold at which there is a significant difference. A Two-sample Assuming Equal Variances t-Test was run on daily precipitation data for each year from June 2 through August 29 (Appendix E). The only significant difference ($p < 0.05$) in daily precipitation was between 2016 and 2021.

3.c. Physical Parameters

3.c.i Comparison to Ambient Water Quality Standards for DO

All organisms need oxygen to survive. Dissolved oxygen (DO) is a measure of the amount of oxygen available in water for marine organisms. The dissolved oxygen standard for all three portions of Manhasset Bay is a daily average of 4.8 mg/L, with allowable excursions to not less than 3.0 mg/L[21]. DO above 4.8 mg/L is considered the amount to support most marine life.

[21] https://www.dec.ny.gov/docs/water_pdf/togs116.pdf

As MBPC does not collect continuous dissolved oxygen data, making this standard difficult to compare against. However, we can use it as a reference point for the data points that were collected.[22] DO measurements were taken at the surface.

2017

In 2017, water depth, secchi depth, dissolved oxygen, conductivity/salinity, and pH were not collected until June 26th. All YSI calibration checks were in the acceptable range, except for 7/17 and 7/31 and 8/21, the only date for which a calibration sheet is missing. Additionally, the YSI broke on 7/10, rendering that data unusable.

In 2017, DO levels never went below the 3.0 mg/l minimum threshold. They did, however, dip below the 4.8mg/l threshold on several occasions. On July 24, 2017, DO was below 4.8 mg/l at five of the seven sampling sites: Leeds Pond, Manorhaven, Manorhaven Beach, Baxter Beach, and Great Neck. August 28, 2017, again saw multiple sites below 4.8 mg/L: Leeds Pond, Baxter Beach, Manorhaven Beach, and Great Neck. Great Neck also had low DO on two other dates: July 3, 2017 and August 7, 2017. Leeds Pond also had low DO on August 14, 2017 (Table 10).

Table 10. 2017 comparisons of dissolve oxygen against NYSDEC standards.
Dissolved oxygen concentrations below 4.8mg/L are highlighted in yellow; dissolved concentrations below 3.0mg/L are highlighted in red

Site Name:	MB-1	MB-2	MB-3	MB-4	MB-5	MB-6	MB-7
Date	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)
6/26/2017	11.52	9.7	9.25	8.12		8.18	12.57
7/3/2017	7.66	7.82	9.12	9.43	9.25	8.09	4
7/24/2017	3.9	5.5	4.4	5.79	4.2	4.6	3.6
7/31/2017	5.53	6.89	9.29	5.49	11.56	4.7	8.15
8/7/2017	4.9	7.78	6.1	5.92	5.12	6.46	4.06
8/14/2017	3.53	4.83	6.18	6.22	5.99	6.08	5.04
8/28/2017	3.08	5.65	5.66	5.89	3.04	4.75	3.56

[22] https://www.dec.ny.gov/docs/water_pdf/togs116.pdf

2019

2019 was the first year that the YSI ProDSS multiparameter probe was used. Unfortunately, the calibration data for 2019 is missing, making this data questionable, despite being within the acceptable precision range as outlined in the DUAR[23]. This data should be used conservatively.

In 2019, DO levels went below the 3.0 mg/l minimum threshold twice and both times at Great Neck (MB-7): on 7/8 (1.81 mg/l) and on 7/29 (2.34 mg/l). DO levels were at that threshold (3.03 mg/l) on 8/26 at Baxter Beach (MB-5). Given the urbanized nature of these two sites, this is not surprising.

DO levels went below the 4.8mg/l threshold on several occasions. On July 8th, DO was below this threshold at Leeds Pond, Baxter Beach, and Great Neck. On July 22nd at Great Neck (MB-7; 3.34 mg/l). On July 29th at Leeds Pond, Baxter Beach, and Great Neck. On August 12th at Kennelworth and Great Neck. On August 19th at Leeds Pond and Great Neck. And on August 26th at Leeds Pond, Baxter Beach, and Great Neck (Table 11).

Table 11. 2019 comparisons of dissolve oxygen against NYSDEC standards.

Dissolved oxygen concentrations below 4.8mg/L are highlighted in yellow; dissolved concentrations below 3.0mg/L are highlighted in red.

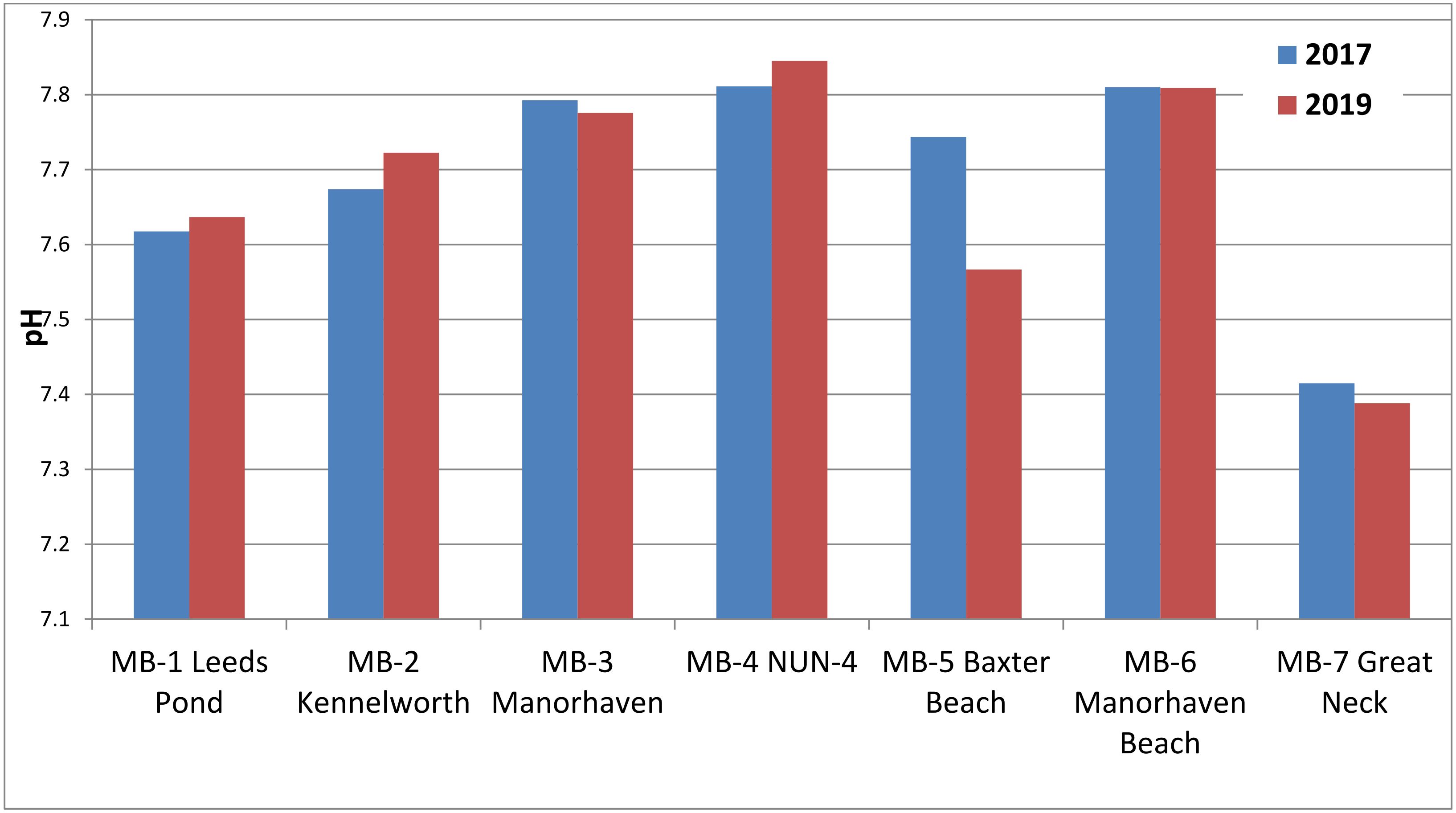
Site Name:	MB-1	MB-2	MB-3	MB-4	MB-5	MB-6	MB-7
Date	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (mg/L)
6/10/2019	6.53	9.32	7.92	8.40	7.45	7.40	7.61
6/17/2019	7.91	7.76	7.47	7.73	7.56	13.31	8.13
6/24/2019	9.02	7.26	11.03	12.88	7.65	8.51	5.79
7/1/2019	10.37	8.41	6.88	8.53	7.92	7.59	8.13
7/8/2019	3.55	7.09	7.31	7.87	4.50	5.95	1.81[24]
7/15/2019	7.94	5.97	6.78	8.33	6.58	7.09	7.42
7/22/2019	7.47	9.17	8.08	8.70	4.98	7.52	3.34
7/29/2019	3.97	6.45	9.99	10.15	3.93	8.89	2.34
8/5/2019	5.15	7.40	6.31	6.39	5.06	5.25	5.55
8/12/2019	7.54	4.32	6.35	6.79	8.30	8.29	3.56
8/19/2019	4.57	6.67	9.48	7.74	5.68	8.15	4.26
8/26/2019	4.01	5.64	5.27	5.44	3.03	5.48	4.01

[23] Data Usability Assessment Report for Manhasset Bay Bacteriological Assessment for Summers 2016 through 2021; available at: https://manhassetbayprotectioncommittee.org/PDF_PUBLIC/Water_Quality_Data/
[24] The Connecticut Department of Energy and Environmental Protection (CTDEEP) does sampling throughout Long Island Sound. Their data did not show hypoxia on this date.

3.c.ii pH

pH is a measure of hydrogen ions in a solution. Climate change is expected to lower the pH of ocean and estuarine waters, making them acidic. A consequence of an acidic Manhasset Bay would be that shellfish could no longer grow, as the shells of juvenile shellfish would dissolve. For this reason, the Committee has chosen to begin monitoring pH in Manhasset Bay. In 2017, pH ranged from 7.15 to 8.28 across the Bay. In 2019, pH ranged from 7.0 to 8.3 across the Bay (Appendix B). Average pH for each station and year was charted and this shows that pH at the Great Neck (MB-7) station was lower than all the other stations (Fig. 5).

Figure 5. Average pH by station and year



3.c.iii Salinity

Manhasset Bay is an estuary and estuaries have brackish water (a mix of salt water from the ocean water and freshwater from the land). Ocean water is around 35 psu (practical salinity units) and freshwater is 0 psu. Salinity at stations that are in more remote sections of the Bay (MB-5 and MB-7) seemed to be lower than at other stations in the Bay (Fig. 6).

In 2017, salinity ranged from 23.56 to 26.31 (Appendix B) and showed a strong negative correlation with rainfall that occurred two-days prior to sampling at all stations ($p < -0.70$). This meant, that rain two days before would lead to lower salinity. This correlation may not have shown in rainfall the day before or day of sampling, because the number of rainfall events in this date range was few. There was no correlation between salinity and tidal height.

Salinity in 2019 ranged from 21.44 to 25.95 (Appendix B). There was no correlation between salinity and rainfall in 2019. A Pearson analysis between salinity and tidal height was not run for 2019 data.

3.c.iv Water Clarity

Water clarity is a measurement of how deep light penetrates, which is important for marine algae and plants that use photosynthesis to generate energy. Water clarity is determined using a secchi disk. The larger the secchi depth, the deeper light penetrates. Secchi disk depths were collected in 2017, 2018, and 2019 (Appendix B).

Average secchi disk depths were almost always higher at the Kennelworth (MB-2) and NUN-4 (MB-4) stations (Fig. 7), which is to be expected as these two stations experience the most water exchange with Long Island Sound.

Figure 6. Average salinity (psu) by station and year

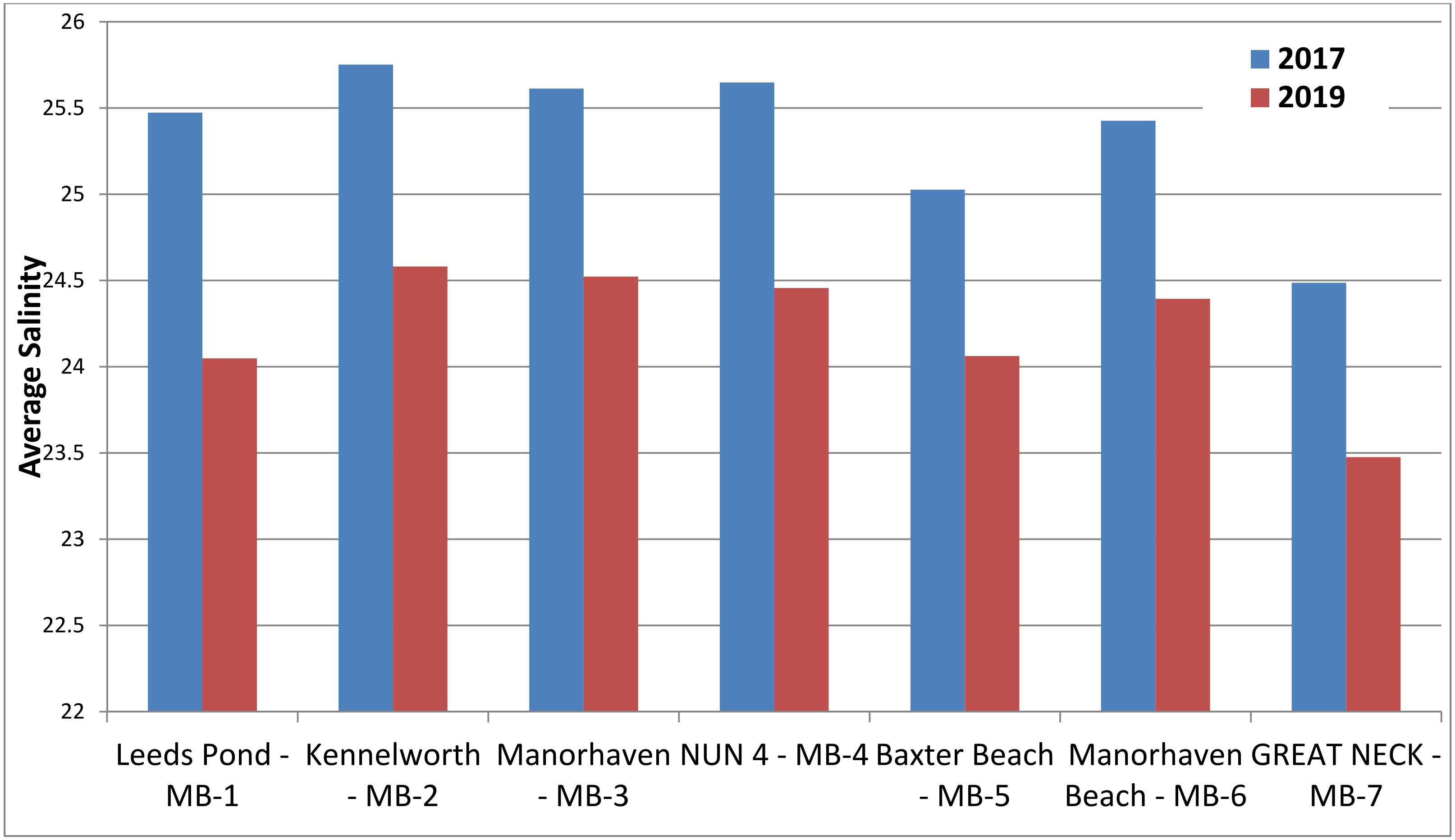
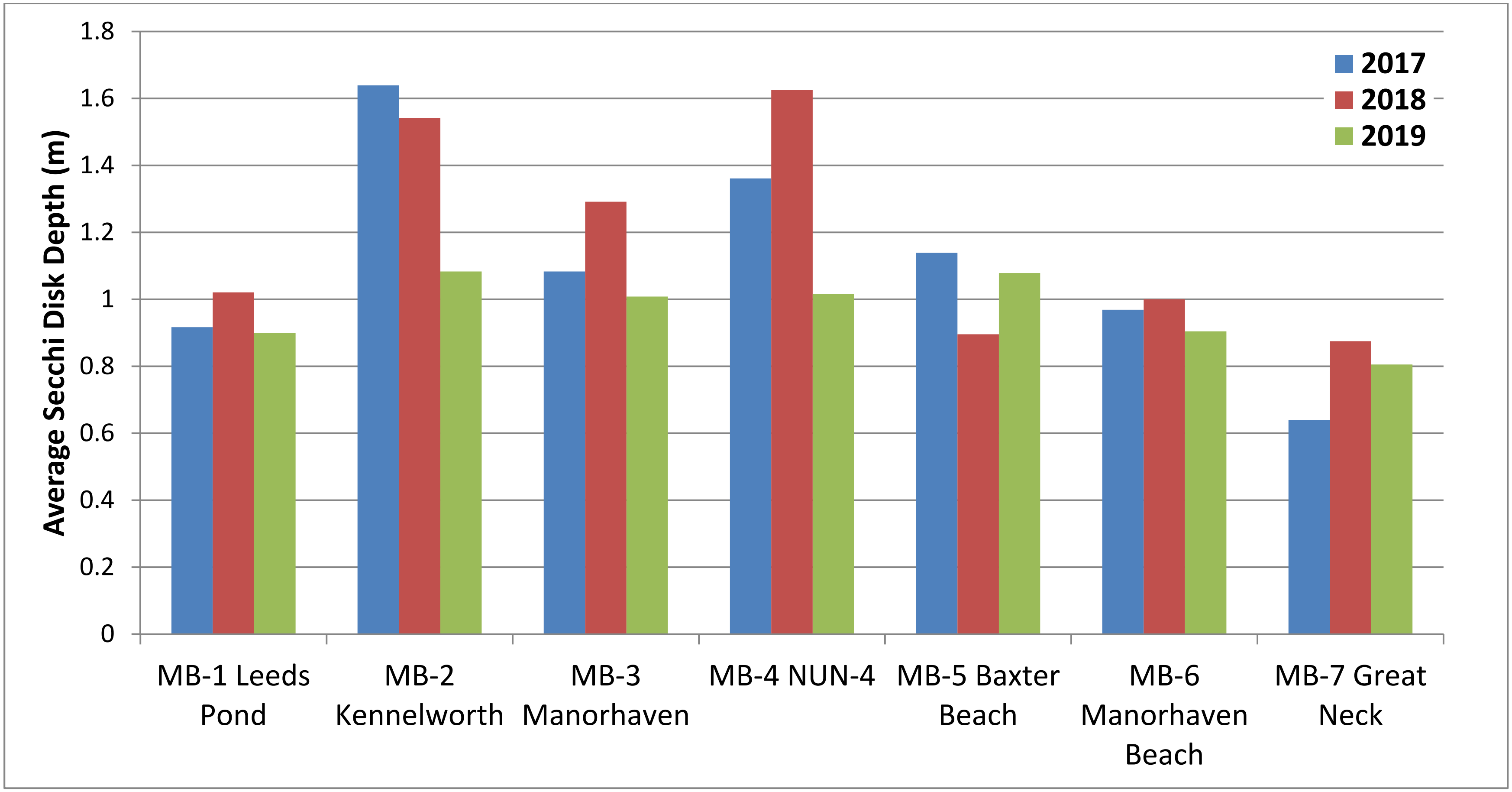


Figure 7. Average secchi disk depths (m) for all stations by year



3.d How Do Rainfall and Temperature Affect Physical Parameters

Since water quality parameters were collected inconsistently from year-to-year, this data cannot be compared over the course of years to identify trends.

3.d.i Water Clarity v. Rainfall

Water clarity is a measurement of how deep light penetrates, which is important for marine algae and plants that use photosynthesis to generate energy. Water clarity is determined using a secchi disk. Secchi disk depths were collected in 2017, 2018, and 2019. As outlined below, there was no correlation between water clarity and rainfall.

2017 Water Clarity v. Rainfall

In 2017, water depth, secchi depth, dissolved oxygen, conductivity/salinity, and pH were not collected until June 26th. Additionally, as outlined in the DUAR, the 8/7/2017 secchi disk measurements were not used. A Pearson Correlation was run for 2017 secchi disk depth against precipitation data, but no correlation was indicated ($-0.7 < p < 0.7$).

Table 12. Pearson correlations for 2017 secchi disk depth data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. There were no significant findings.

	Pearson coefficient		
	Two-days prior	One-day prior	Day-of
MB-1	-0.116	0.364	0.377
MB-2	0.164	0.128	0.146
MB-3	-0.168	-0.101	-0.115
MB-4	0.006	0.507	0.535
MB-5	-0.576	-0.096	-0.109
MB-6	-0.509	0.570	0.591
MB-7	-0.439	-0.131	-0.122

A Pearson Correlation was also run for 2017 secchi disk depth against tidal height, but no correlations were found between the two data series (Table 13). This correlation was only done for 2017.

Table 13. Pearson correlations for 2017 secchi disk depth data v. tidal height There were no significant findings.

	Pearson coefficient
MB-1	0.62817964
MB-2	0.29098625
MB-3	0.44706648
MB-4	0.25457122
MB-5	0.39129279
MB-6	0.33012283
MB-7	0.32353937

2018 Water Clarity v. Rainfall

No quality assurance measures were used for secchi disk depth in 2018, so this data should be used conservatively. A Pearson Correlation was run for 2018 secchi disk depth against precipitation data, but no correlation was indicated ($-0.7 < p < 0.7$; Table 14).

Table 14. Pearson correlations for 2018 secchi disk depth data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. There were no significant findings.

	Pearson coefficient		
	Two-days prior	One-day prior	Day-of
MB-1	-0.080	-0.288	-0.023
MB-2	-0.301	-0.243	-0.239
MB-3	-0.004	-0.340	-0.130
MB-4	-0.625	-0.501	-0.511
MB-5	0.127	-0.148	0.140
MB-6	-0.007	-0.092	-0.002
MB-7	0.037	0.177	-0.029

2019 Water Clarity v. Rainfall

Secchi depth quality assurance ("QA") measurements on 6/24/2019 and 8/5/2019 were above the precision threshold and so these data were removed from analysis. No QA was done on 8/12/2019. A Pearson Correlation was run for 2019 secchi disk depth against precipitation data, but no correlation was indicated ($-0.7 < p < 0.7$; Table 15).

Table 15. Pearson correlations for 2019 secchi disk depth data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. There were no significant findings.

	Pearson coefficient		
	Two-days prior	One-day prior	Day-of
MB-1	0.092	-0.283	-0.570
MB-2	-0.115	-0.264	-0.236
MB-3	-0.311	-0.341	0.165
MB-4	-0.023	-0.322	-0.093
MB-5	-0.190	-0.567	-0.036
MB-6	-0.291	-0.328	-0.161
MB-7	-0.143	0.214	0.190

3.d.ii Effect of Rainfall and Temperature on DO and Salinity

Data on other water quality parameters is only available for 2017 and 2019 as these were the two years a YSI multiparameter probe was used.

2017 Effect of Rainfall and Temperature on DO

In 2017, water depth, secchi depth, dissolved oxygen, conductivity/salinity, and pH were not collected until June 26th. All YSI calibration checks were in the acceptable range, except for 7/17 and 8/21, the only date for which a calibration sheet is missing. These data points were not used. Additionally, the YSI broke on 7/10, rendering that data unusable. All Pearson coefficients are given in the table below.

Table 16. Pearson correlations for 2017 dissolved oxygen data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling as well as temperature. Significant findings are highlighted.

Station ID	**Pearson coefficient**			
	Rainfall Two-days prior	Rainfall One-day prior	Rainfall Day-of	Temperature
MB-1	0.713	-0.271	-0.267	-0.850
MB-2	0.560	-0.359	-0.300	-0.806
MB-3	0.152	-0.596	-0.617	-0.397
MB-4	0.308	-0.268	-0.216	-0.401
MB-5	-0.422	-0.351	-0.369	0.147
MB-6	0.448	-0.433	-0.353	-0.523
MB-7	0.706	-0.295	-0.395	-0.791

Leeds Pond (MB-1)

At the Leeds Pond site, dissolved oxygen was shown to have a negative correlation ($p < -0.70$; Table 16) with water temperature. This means that when the water got warmer, dissolved oxygen went down. This is a well-known fact: that warmer water holds less dissolved gases and vice versa.

At this site, dissolved oxygen was shown to have a positive correlation ($p > 0.70$; Table 16) with rainfall that occurred two days prior to sampling. This means that DO increased two days after a rainfall. This can be explained as rainfall carries nutrients to the water, which increases photosynthesis, thus raising dissolved oxygen.

Kennelworth (MB-2)

At the Kennelworth site, dissolved oxygen was shown to have a negative correlation ($p < -0.70$; Table 16) with water temperature. This means that when the water got warmer, dissolved oxygen went down. This is a well-known fact that warmer water holds less dissolved gases and vice versa. There was no correlation between DO and rainfall (Table 16).

Manorhaven (MB-3), NUN-4 (MB-4), Baxter Beach (MB-5), Manorhaven Beach (MB-6)

There were no correlations between rainfall or temperature and DO at these sites (Table 16).

Great Neck (MB-7)

At the Great Neck site, dissolved oxygen was shown to have a negative correlation ($p < -0.70$; Table 16) with water temperature. This means that when the water got warmer, dissolved oxygen went down. This is a well-known fact that warmer water holds less dissolved gases and vice versa.

At this site, dissolved oxygen was shown to have a positive correlation ($p > 0.70$; Table 16) with rainfall that occurred two days prior to sampling. This means that DO increased two days after a rainfall. This can be explained as rainfall carries nutrients to the water, which increases photosynthesis, thus raising dissolved oxygen.

2017 Effect of Rainfall and Tide on Salinity – all sites

Salinity was shown to have a negative correlation ($p < -0.7$) with rainfall that occurred two days before sampling at all sites, indicating that increased rainfall lead to decreased salinity. Significance was possibly not indicated for any rainfall occurring closer to sampling due to the limited number of rain events within that window. A Pearson Correlation was run for salinity against tidal height, but no correlation was indicated ($-0.7 < p < 0.7$; Table 17).

Table 17. Pearson correlations for 2017 salinity data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling as well as tidal height. Significant findings are highlighted.

Station ID	Pearson coefficients			
	Rainfall Two-days prior	Rainfall One-day prior	Rainfall Day-of	Tidal height
MB-1	-0.927	-0.187	-0.118	0.460530568
MB-2	-0.924	-0.199	-0.133	0.502326794
MB-3	-0.823	0.076	0.160	0.573225161
MB-4	-0.776	0.073	0.150	0.574882287
MB-5	-0.875	0.048	0.126	0.54626679
MB-6	-0.797	-0.168	-0.095	0.353475683
MB-7	-0.740	-0.523	-0.457	0.290406589

2019 Effect of Rainfall and Temperature on DO and Salinity – all sites
2019 was the first year that the YSI ProDSS multiparameter probe was used. Unfortunately, the calibration data for 2019 is missing, making this data questionable, despite being within the acceptable precision range[25]. This data should be used conservatively.

There was no correlation (-0.7 < p < 0.7) between dissolved oxygen and water temperature at any site (Table 18). There was also no correlation (-0.7 < p < 0.7) shown between dissolved oxygen and rainfall that occurred day-of, one day before, or two-days before sampling (Table 18). Additionally, there was no correlation (-0.7 < p < 0.7) shown between salinity and rainfall that occurred day-of, one day before, or two-days before sampling (Table 19). No correlations were run for tidal height in 2019.

Table 18. Pearson correlations for 2019 dissolved oxygen data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling as well as temperature. There were no significant findings.

Station ID	Pearson coefficients			
	Rainfall Two-days prior	Rainfall One-day prior	Rainfall Day-of	Temperature
MB-1	-0.009	-0.245	0.118	-0.098
MB-2	0.150	-0.074	0.658	-0.394
MB-3	-0.314	0.322	0.074	0.151
MB-4	-0.285	-0.086	0.080	-0.082
MB-5	-0.065	-0.045	-0.035	-0.520
MB-6	-0.381	0.096	-0.071	0.023
MB-7	0.187	-0.095	-0.041	-0.481

[25] Data Usability Assessment Report for Manhasset Bay Bacteriological Assessment for Summers 2016 through 2021; available at: https://manhassetbayprotectioncommittee.org/PDF_PUBLIC/Water_Quality_Data/

Table 19. Pearson correlations for 2019 salinity data v. rainfall in the windows of two-days prior to sampling, one-day prior to sampling, and day of sampling. There were no significant findings.

Station ID	Pearson coefficients		
	Rainfall Two-days prior	Rainfall One-day prior	Rainfall Day-of
MB-1	0.14	0.08	-0.01
MB-2	0.09	0.37	-0.18
MB-3	0.18	0.31	-0.16
MB-4	0.16	0.31	-0.21
MB-5	0.26	0.30	-0.13
MB-6	0.20	0.34	-0.20
MB-7	-0.18	0.36	-0.08

3.f Is There a Spatial Difference in Bacteria Concentrations Within the Bay

Plotting the geometric mean of Enterococci bacteria counts by station into a line graph clearly and quickly shows where the highest counts are generally found. Additionally, as this is the standard used by NYSDEC, it gives an idea of how these stations fare compared to the standard. The standard states that the geometric mean of Enterococci samples collected over any consecutive 30-day period shall not exceed 35 CFU/100 mL.

3.f.i Summer of 2016

In 2016, Kennelworth (MB-2), the western most station and one expected to experience the most flushing with Long Island Sound, had the second highest rolling geometric mean of all the stations. Leeds Pond (MB-1), which is in the less densely populated central-eastern Bay, had the highest rolling geometric mean and is the only station to have exceeded the standard in 2016 (Fig. 8).

3.f.ii Summer of 2017

This is the first year that Great Neck (MB-7) was sampled and, as expected, it had the highest rolling geometric mean of Enterococci. The Great Neck station is located in the narrow, shallow back portion of the Bay, which is densely populated and does not get much flushing. No station exceeded this standard in 2017. Baxter Beach (MB-5) also had a high rolling geometric mean, but this follows suit as this is also located in a site with a dense population and limited flushing (Fig. 9).

3.f.iii Summer of 2018

In 2018, Baxter Beach and Great Neck again had the highest rolling geometric means of Enterococci, which, again, follows the expectation. Leeds Pond (MB-1) and Manorhaven Beach (MB-6) also had elevated rolling geometric means. As expected, NUN-4 (MB-4), in the central basin, and Kennelworth (MB-2) on the western shore had among the lowest rolling geometric means. No station exceeded the rolling geometric mean standard for Enterococci (Fig. 10).

Figure. 8. Plot of 2016 geometric means of Enterococci by station

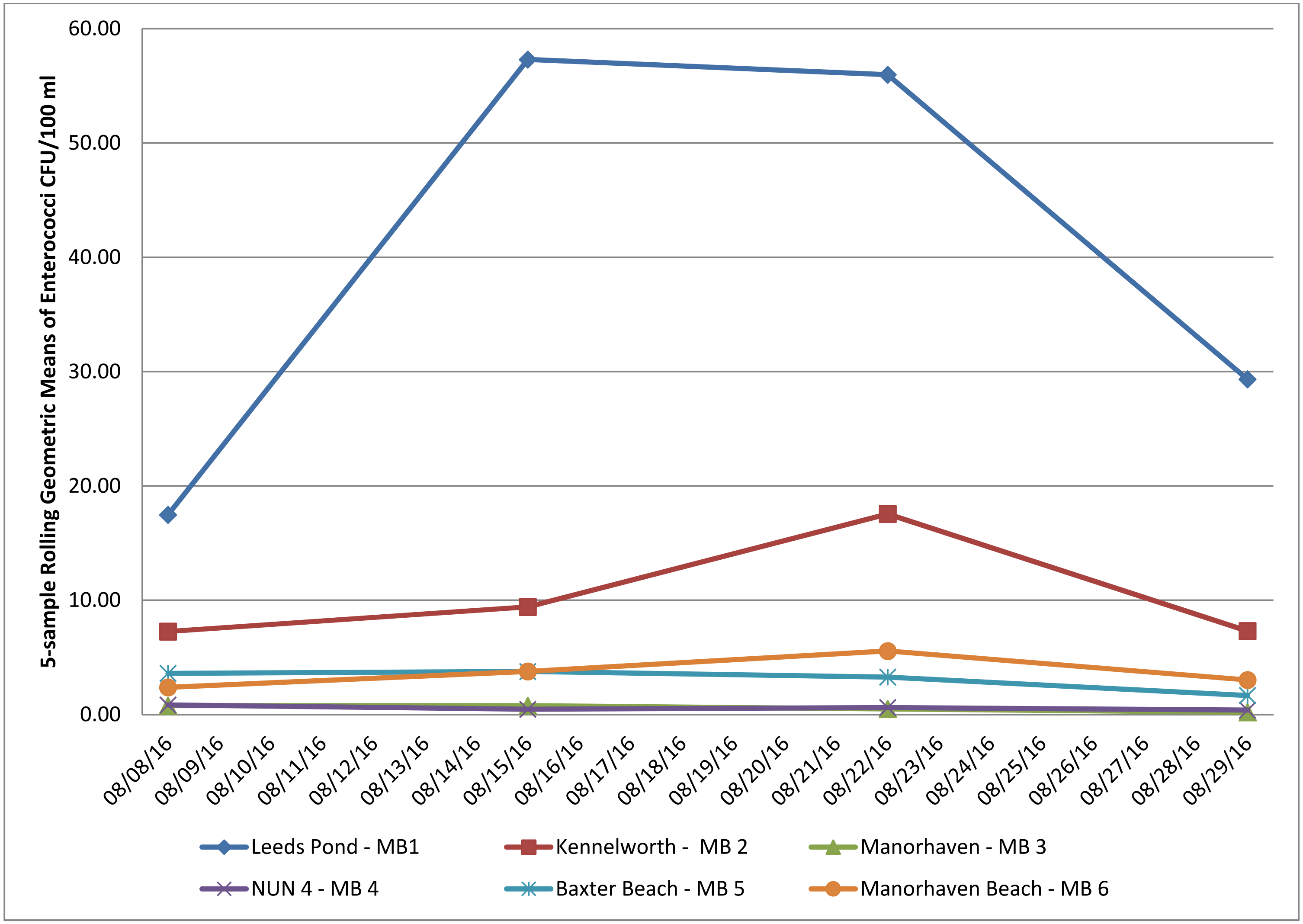


Figure 9. Plot of 2017 geometric means of Enterococci by station

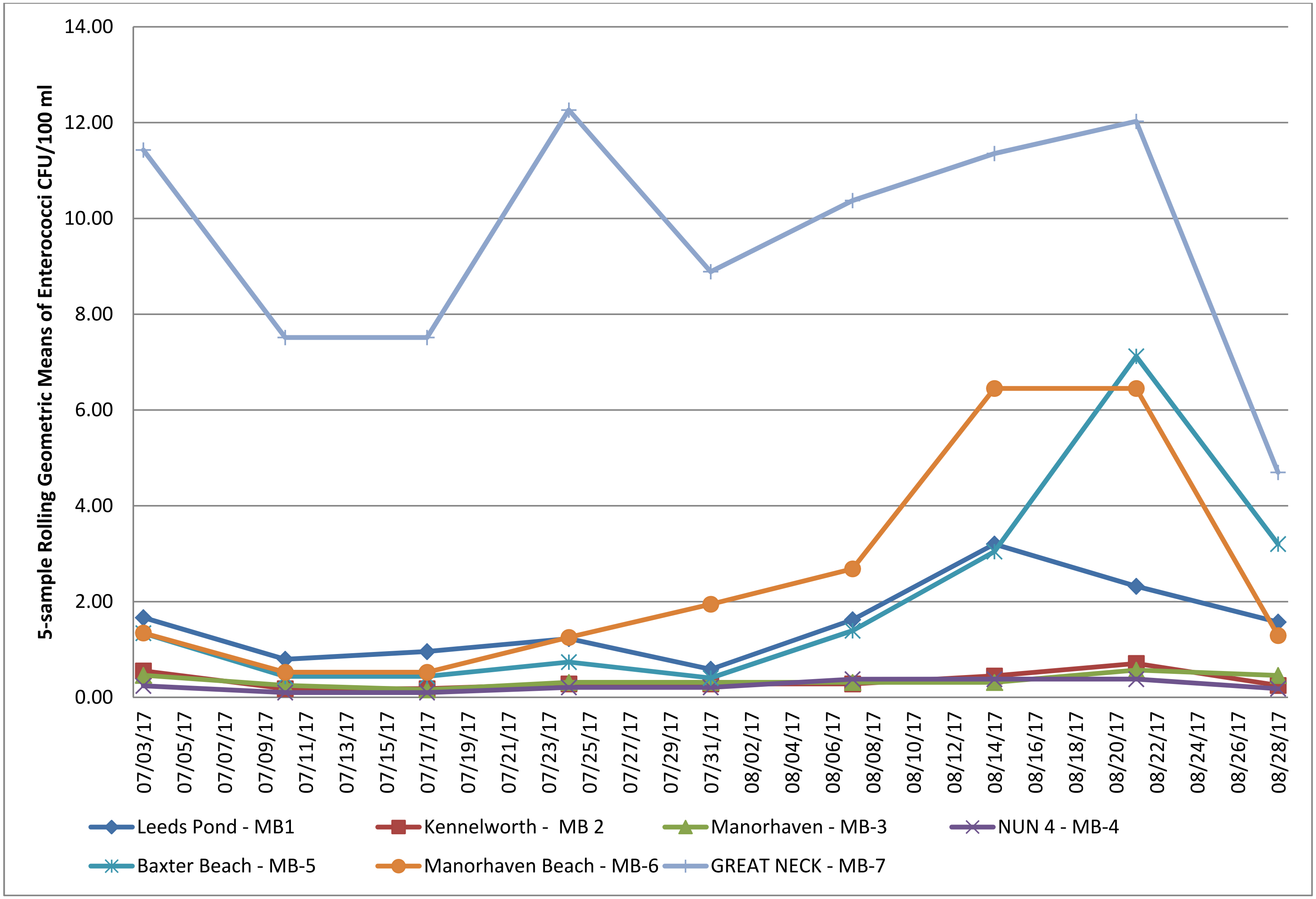


Figure 10. Plot of 2018 geometric means of Enterococci by station

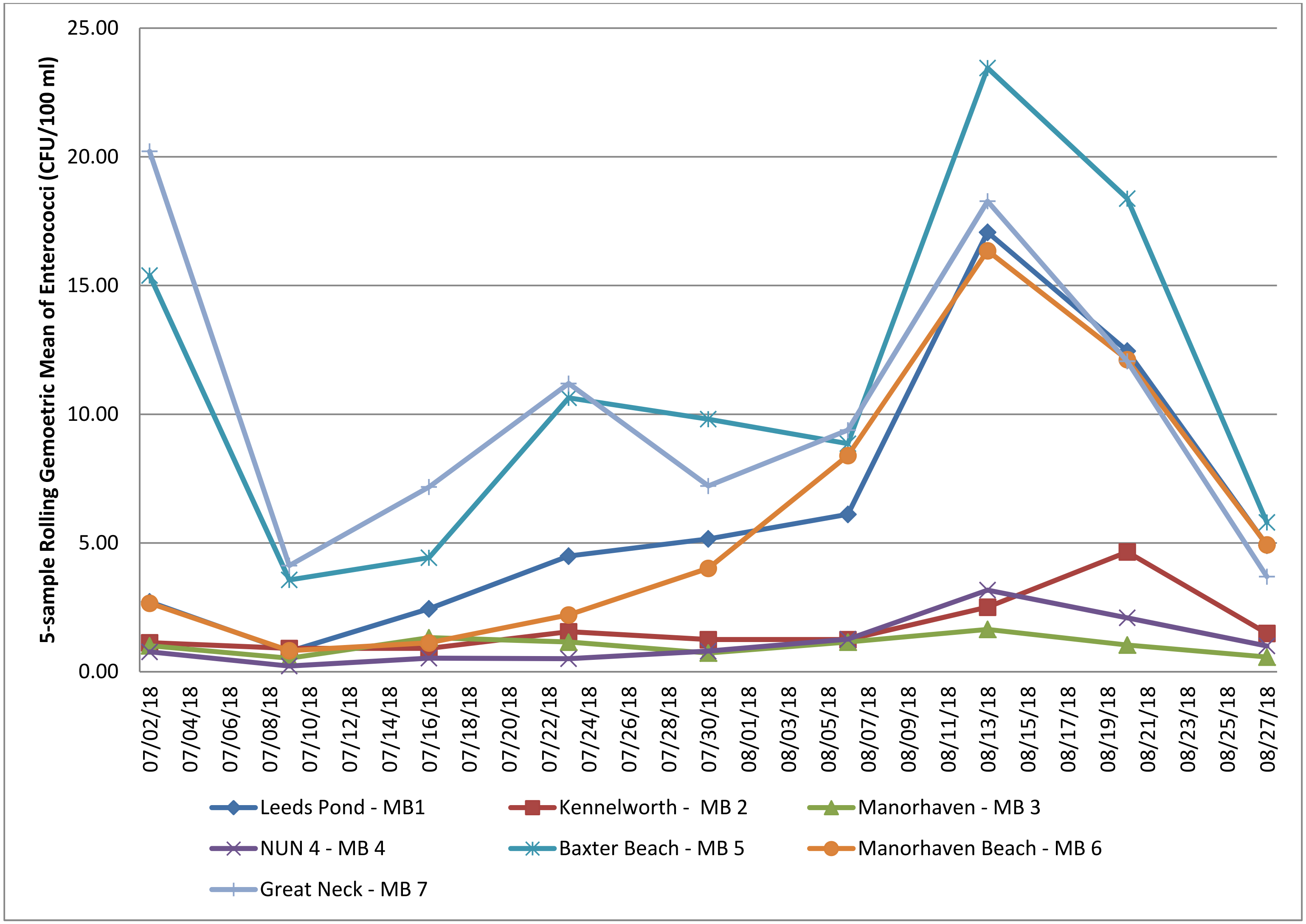


Figure 11. Plot of 2019 geometric means of Enterococci by station

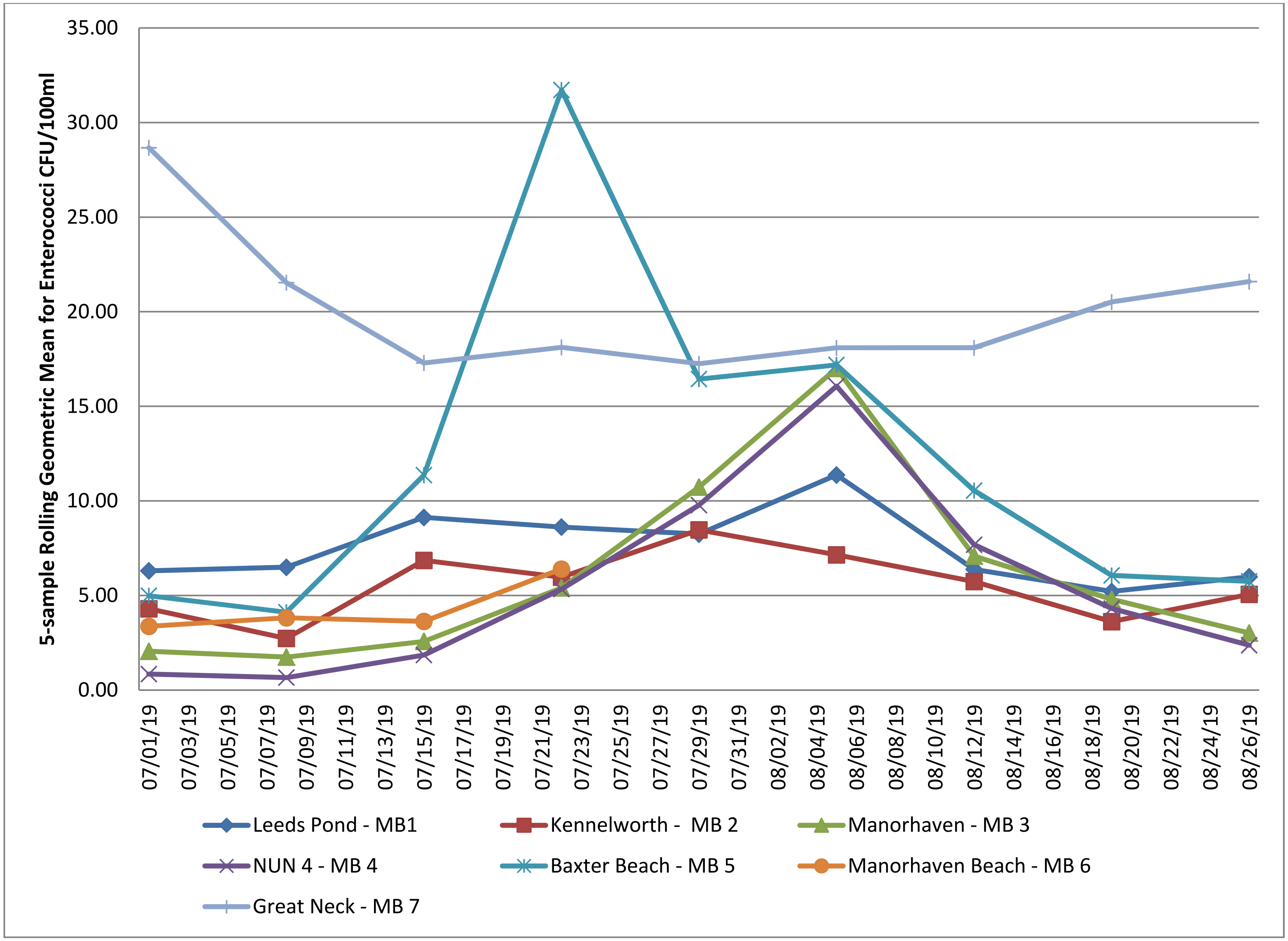


Figure 12. Plot of 2020 geometric means of Enterococci by station

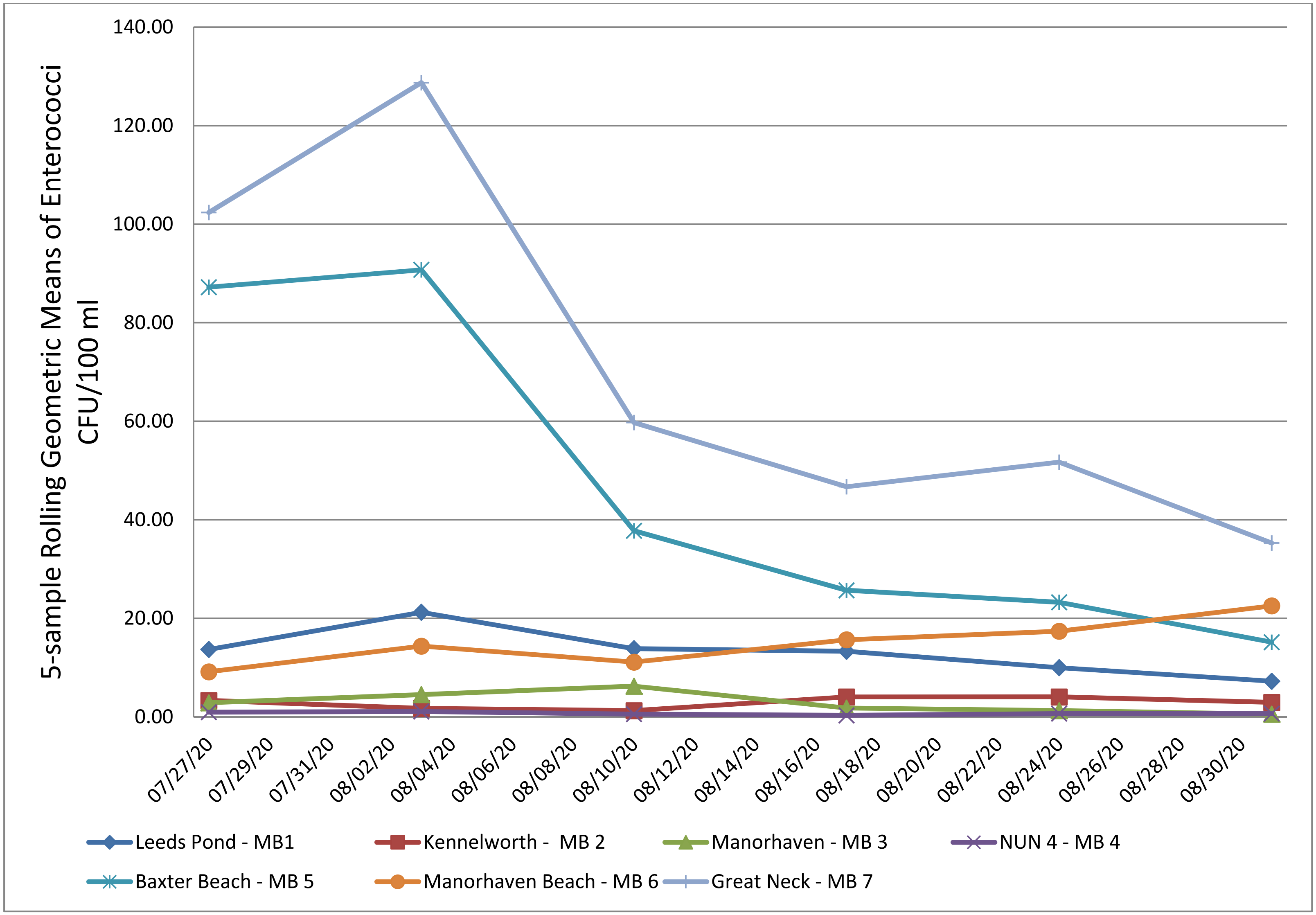
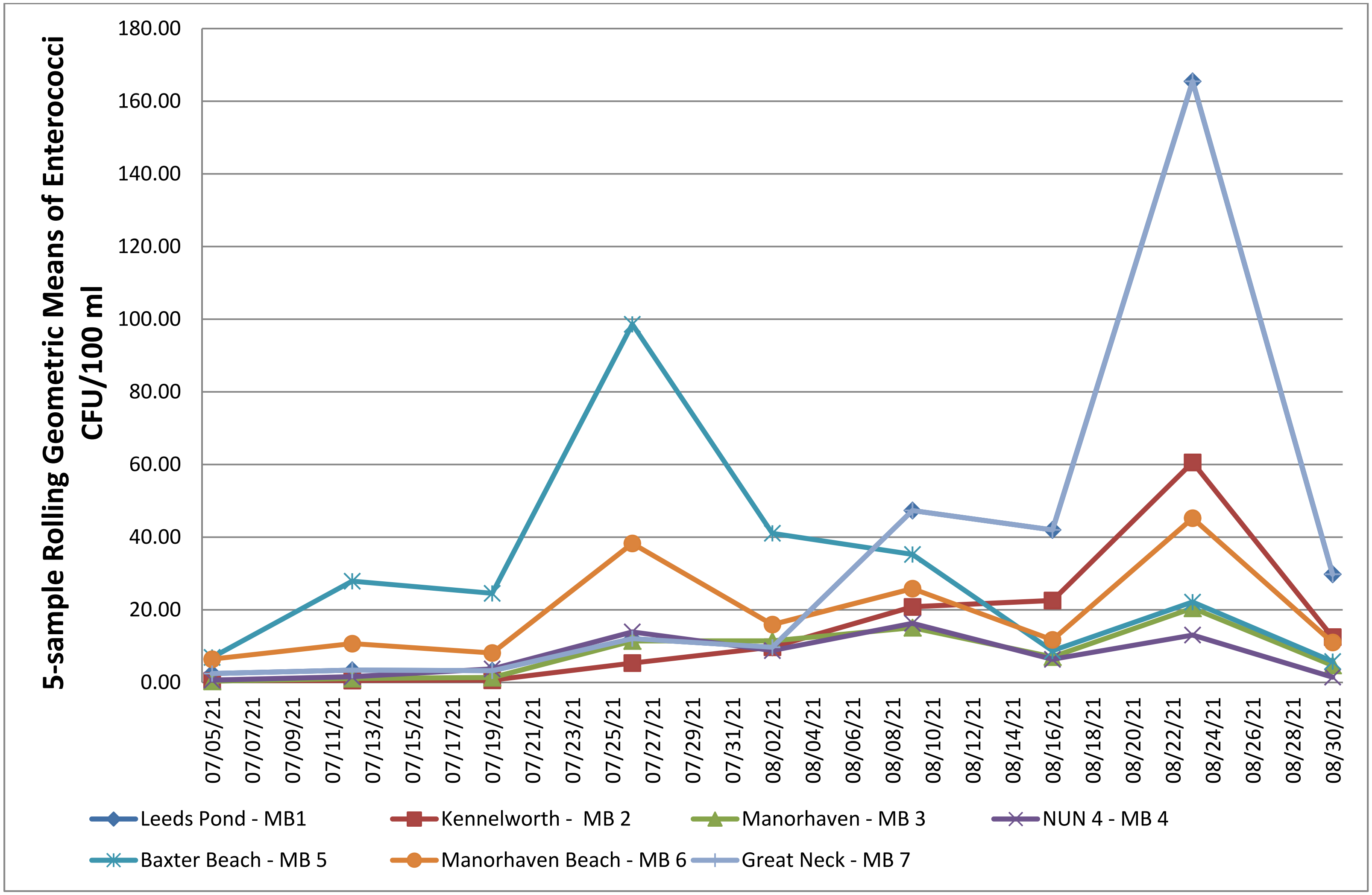


Figure 13. Plot of 2021 geometric means of Enterococci by station



3.f.iv Summer of 2019

In 2018, Baxter Beach and Great Neck again had the highest rolling geometric means of Enterococci, which, again, follows the expectation. Manorhaven Beach (MB-6) was not sampled on July 29th, leaving only four (4) data points for the rolling geometric mean. No station exceeded the rolling geometric mean standard for Enterococci (Fig. 11).

3.f.v Summer of 2020

Great Neck (MB-7) and Baxter Beach (MB-5), again, had the highest rolling geometric means of Enterocci again and both of these sites exceeded this standard multiple times over the summer of 2020. No other station exceeded the rolling geometric mean standard over the course of the 2020 summer sampling season. NUN-4 (MB-4) had the lowest rolling geometric mean for almost every sampling day of the summer (Fig. 12).

3.f.vi Summer of 2021

At the beginning of summer 2021, Baxter Beach (MB-5) had the highest Enterococci geometric means, but this changed in the later summer when Leeds Pond (MB-1) and Kennelworth (MB-2) had the highest Enterococci geometric means. Conversely, Great Neck (MB-7), a site expected to have the highest bacteria counts was among the lowest for the entire summer. Summer 2021 also saw bacteria standards exceeded on multiple occasions and at multiple sites (Fig. 13).

3.g. Are there any trends in interannual bacteria concentrations at each site?

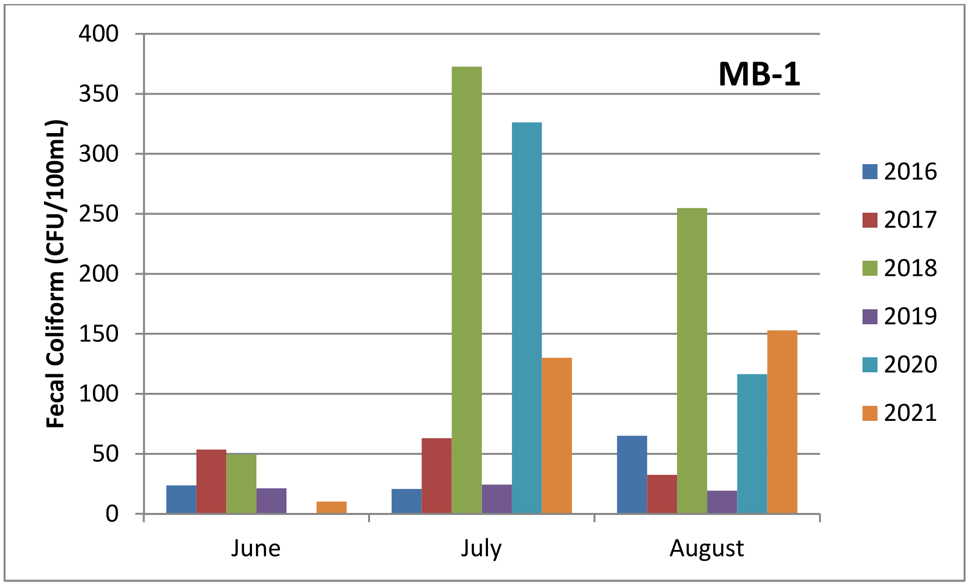
In order to identify if there was any interannual trend in bacteria concentrations, monthly averages for June, July, and August, where available, were plotted for each site in order to quickly visualize any trends (Figs. 14 – 20). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot. Again since this report covers a short time scale (only six (6) years), any observed trends would have to be made conservatively and their limitations understood.

Before outliers (any count above 1,000 CFU/100mL) were removed, July and August averages for 2021 were always highest or close to it as compared to other years. When those outliers (any counts over 1,000 CFU/100mL) were removed for the first four (4) stations, no discernable pattern was evident.

Figure 14. Interannual graphs of monthly averages for June, July, and August for MB-1 (Leeds Pond). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

The following three (3) outliers were removed before plotting: June 6, 2016 Fecal Coliform count; July 26, 2021 Fecal Coliform & Enterococci counts.

a. Fecal Coliform



b. Enterococci

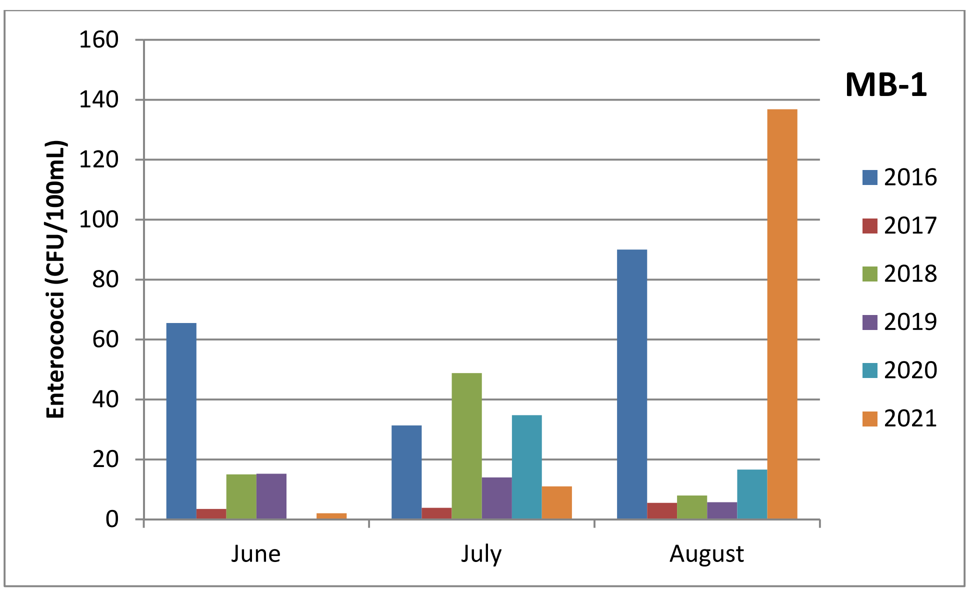
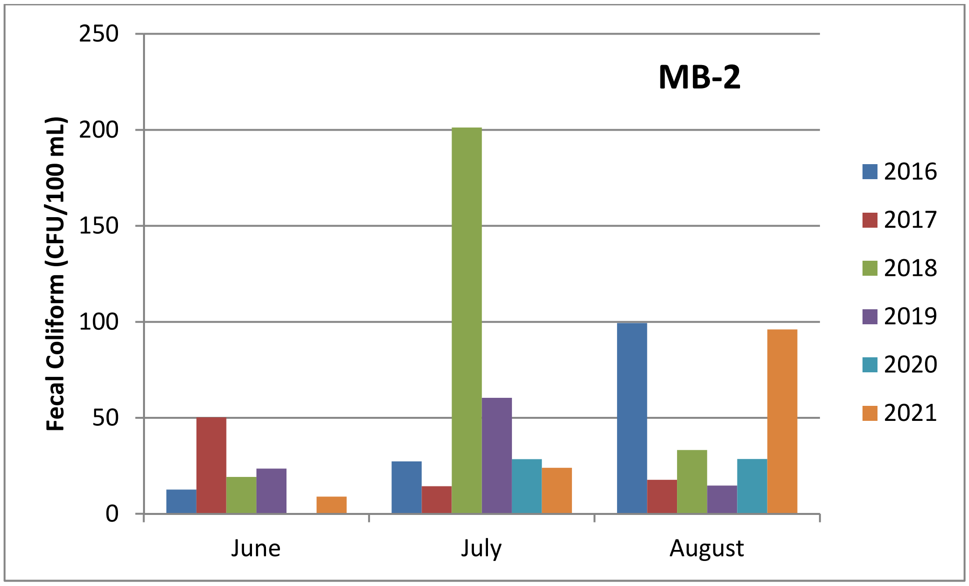


Figure 15. Interannual graphs of monthly averages for June, July, and August for MB-2 (Kennelworth). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

The following three (3) outliers were removed before plotting: June 6, 2016 Fecal Coliform count; July 26, 2021 Fecal Coliform & Enterococci counts.

a. Fecal Coliform



b. Enterococci

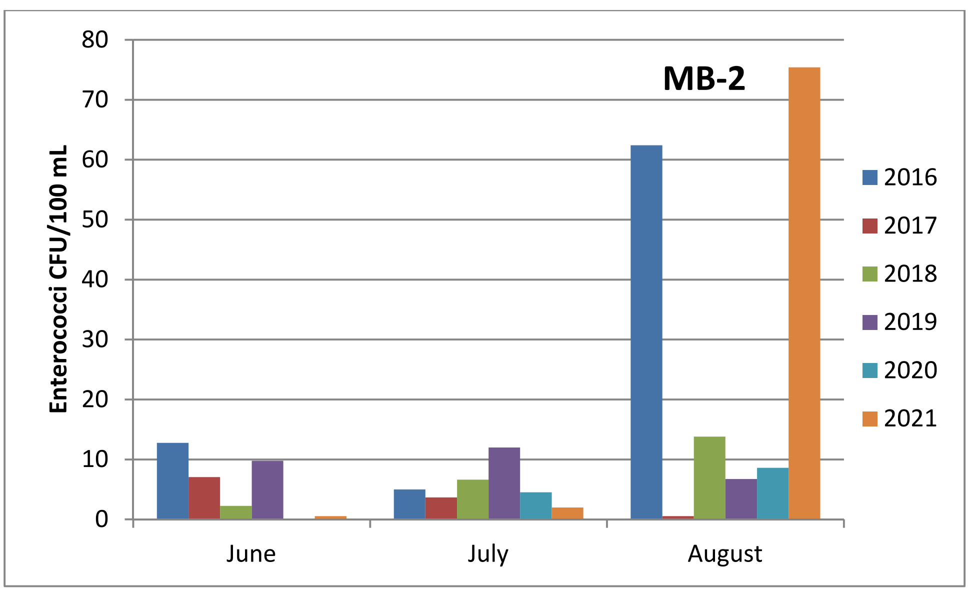
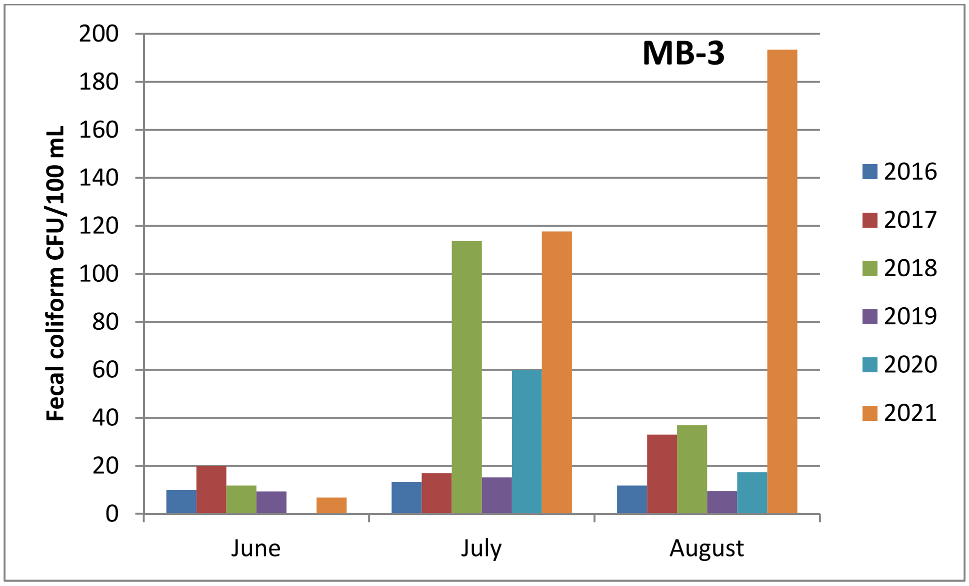


Figure 16. Interannual graphs of monthly averages for June, July, and August for MB-3 (Manorhaven). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

The following three (3) outliers were removed before plotting: June 6, 2016 Fecal Coliform count; July 26, 2021 Fecal Coliform & Enterococci counts.

a. Fecal Coliform



b. Enterococci

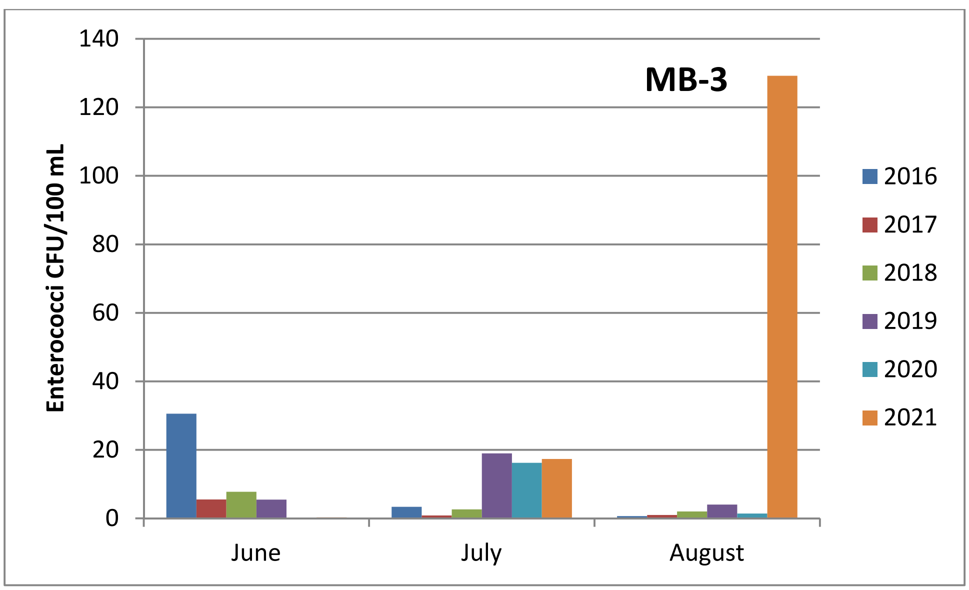
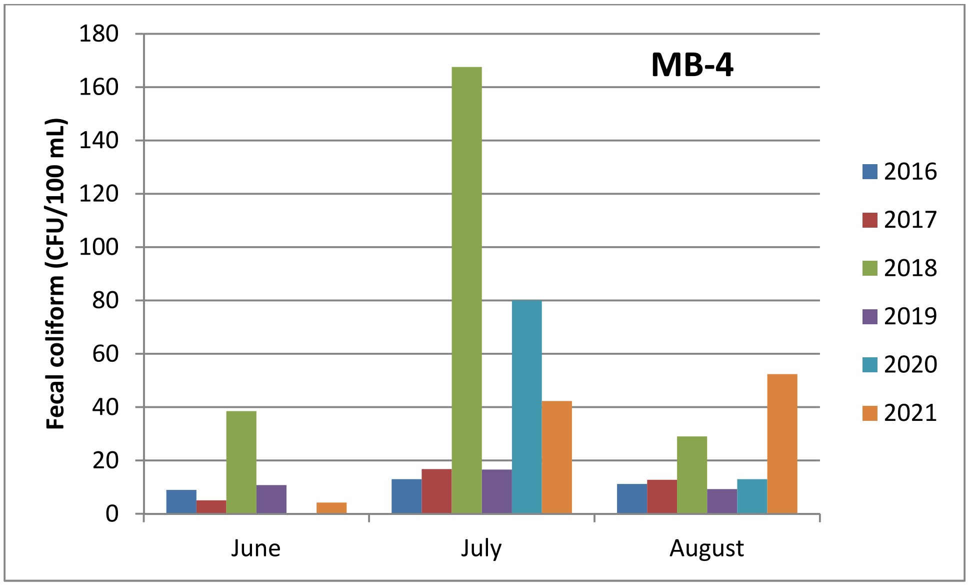


Figure 17. Interannual graphs of monthly averages for June, July, and August for MB-4 (NUN-4). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

The following three (3) outliers were removed before plotting: June 6, 2016 Fecal Coliform count; July 26, 2021 Fecal Coliform & Enterococci counts.

a. Fecal Coliform



b. Enterococci

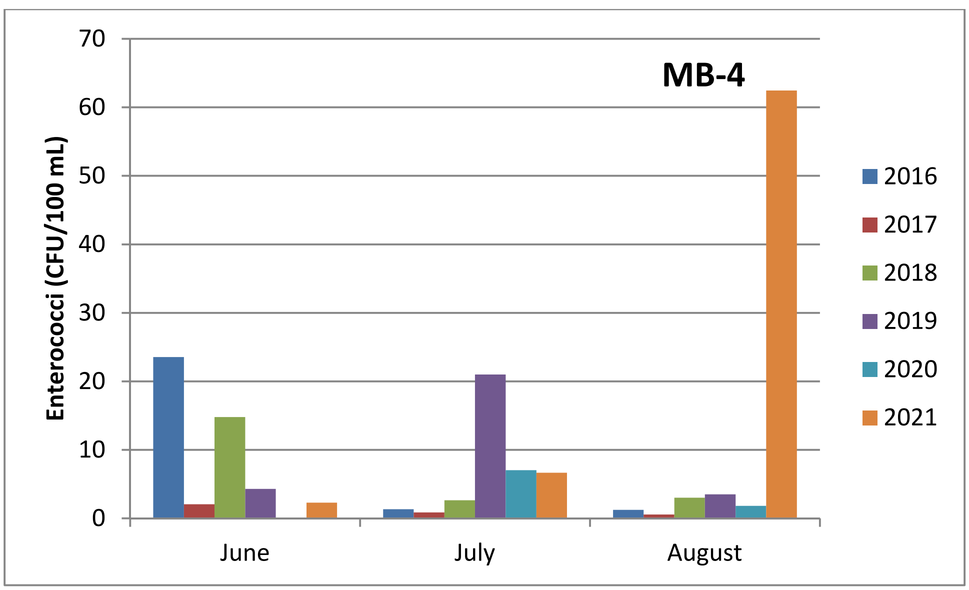
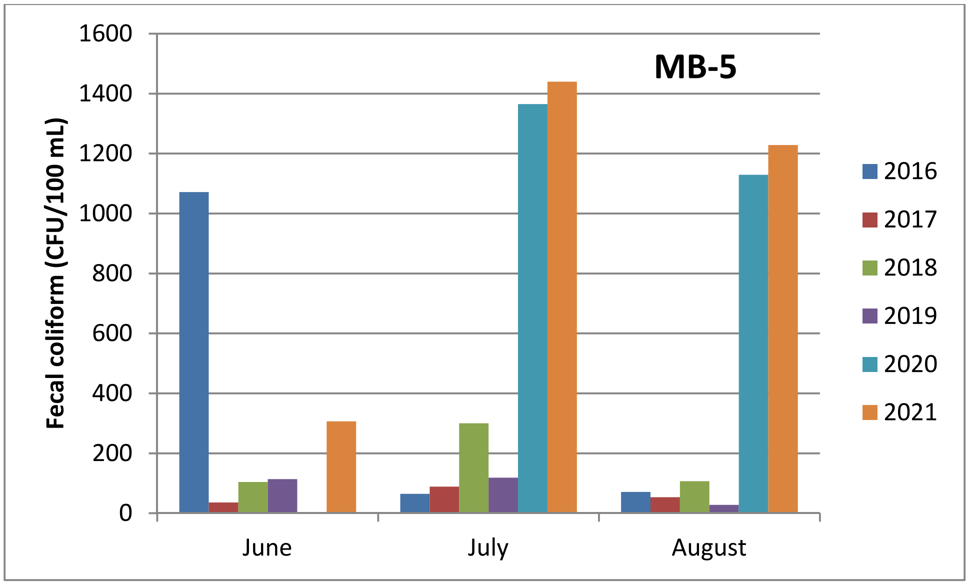


Figure 18. Interannual graphs of monthly averages for June, July, and August for MB-5 (Baxter Beach). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

No outliers were removed before plotting.

a. Fecal Coliform



b. Enterococci

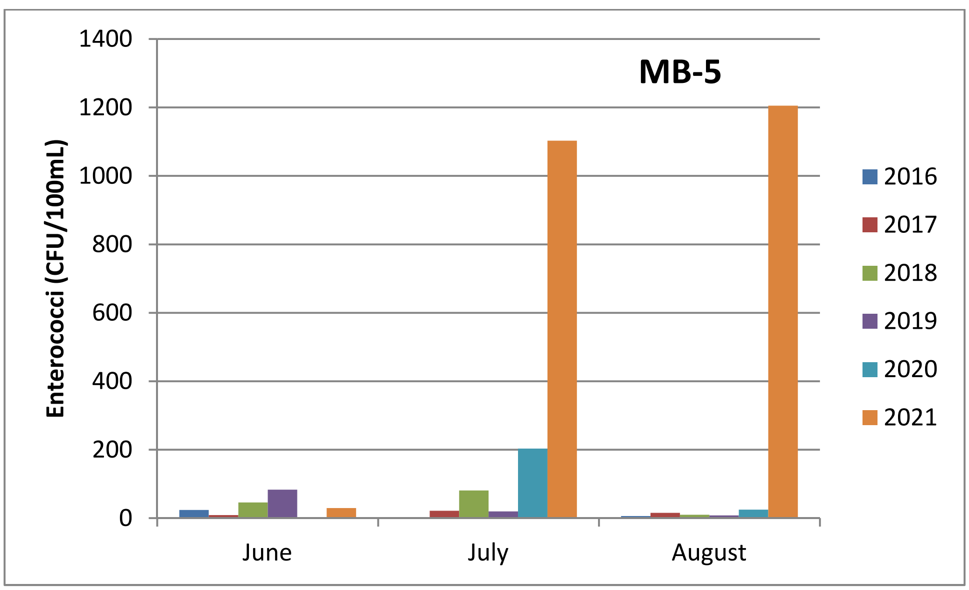
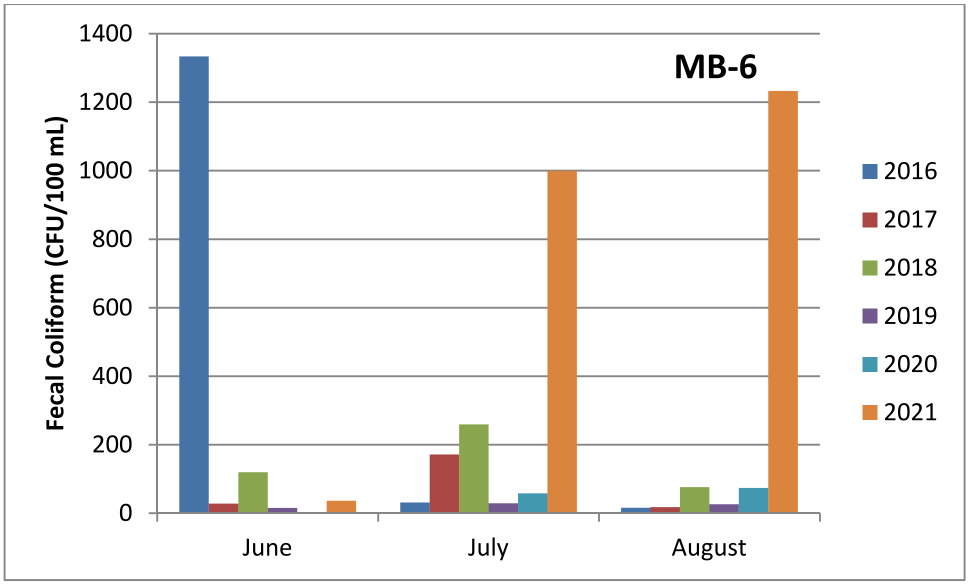


Figure 19. Interannual graphs of monthly averages for June, July, and August for MB-6 (Manorhaven Beach). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

No outliers were removed before plotting.

a. Fecal Coliform



b. Enterococci

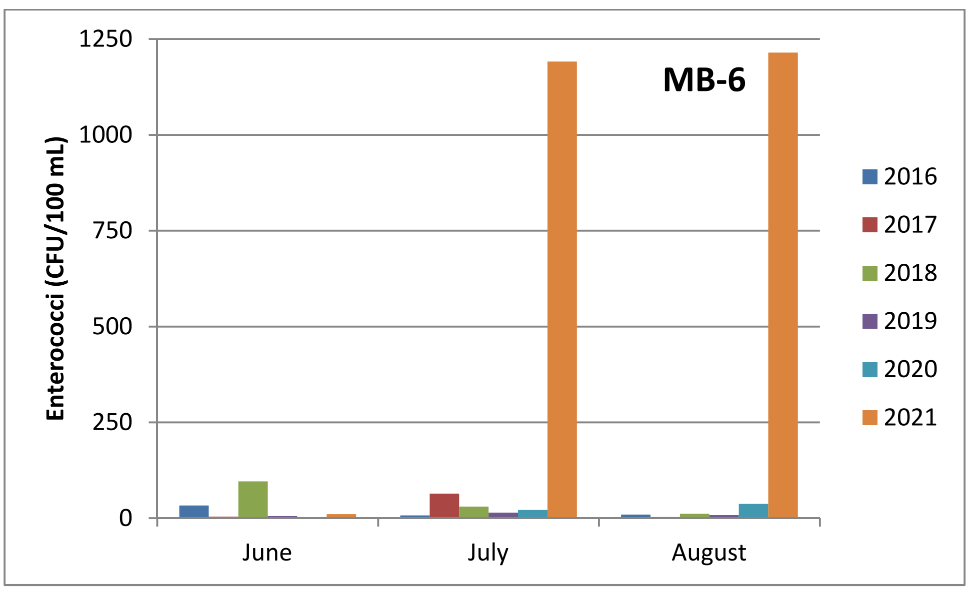
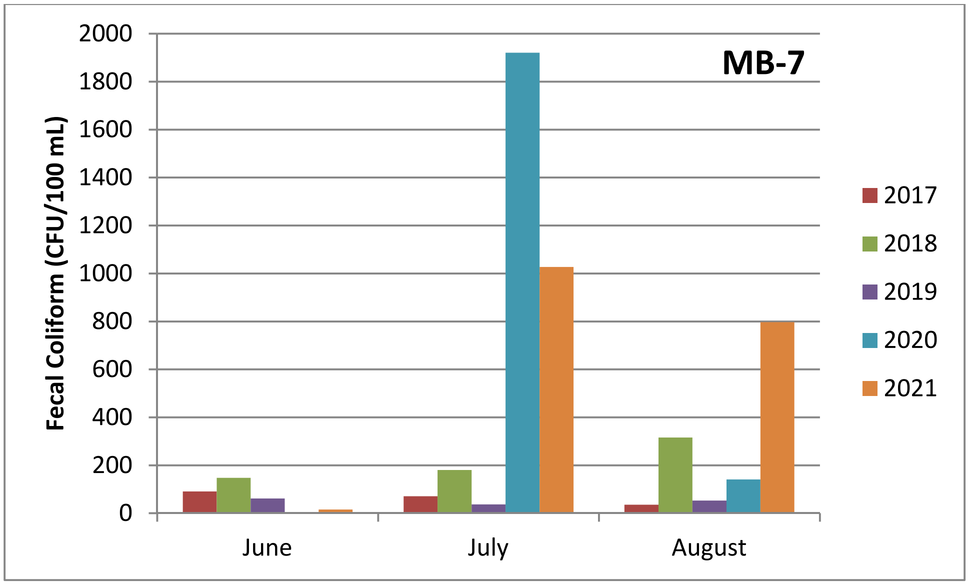


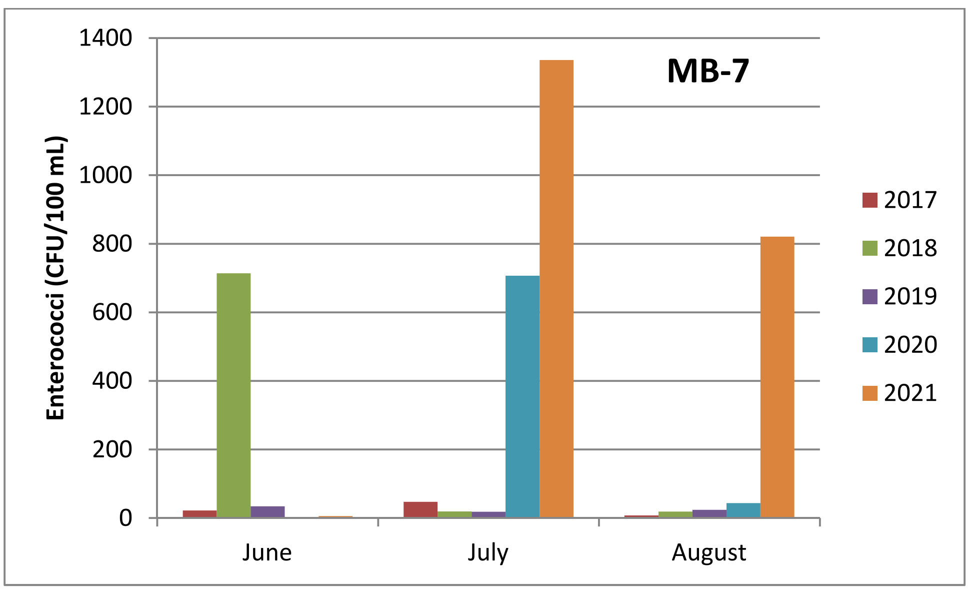
Figure 20. Interannual graphs of monthly averages for June, July, and August for MB-7 (Great Neck). Sampling in 2020 did not begin until the end of June, so there was no June data for this year to plot.

No outliers were removed before plotting.

a. Fecal Coliform



b. Enterococci



4 Discussion

4.a Are in-bay bacteria levels safe for swimming?

This is a question the Committee is asked regularly. However, the data over the reporting period (2016 – 2021) showed no clear pattern that would lead to the ability to answer this definitively. Additionally, it was impossible to identify a distinct rainfall influence on bacteria exceedances at any station in the reporting period. This is consistent with what the Coalition to Save Hempstead Harbor reported in their 2021 Water Quality Report for Hempstead Harbor.[26]

4.b Is there relationship between counts of the two indicator bacteria species and rainfall and can rainfall account for exceedances?

Again, unfortunately, the data over the reporting period (2016 – 2021) showed no clear pattern that would lead to the ability to answer this definitively. For example, in 2016 and 2017, all exceedances of the bacteria standards except one (July 18, 2016 at Baxter Beach) can be linked to rainfall. However, in 2018, only one exceedance (June 4, 2018) can be attributed to rainfall. And 2019 data showed no link between rainfall and bacteria counts.

4.c How do abiotic factors such as precipitation affect other water quality parameters?

Again, unfortunately, the data over the reporting period (2016 – 2021) showed no clear pattern that would lead to the ability to answer this definitively. For example, in 2017, salinity was shown to have a negative correlation ($p < -0.7$) with rainfall that occurred two days before sampling at all sites. But, in 2019, this does not remain true as there was no correlation shown between salinity and rainfall at any site.

There was consistency in that there was no correlation between water clarity and rainfall for the years secchi disk depths were recorded (2017 – 2019).

In 2017, at the Leeds Pond, Kennelworth, and Great Neck sites, dissolved oxygen was shown to have a negative correlation ($p < -0.70$) with water temperature. This means that when the water got warmer, dissolved oxygen went down. This is a well-known fact: that warmer water holds less dissolved gases and vice versa. But this is not consistent: no other sites in 2017 and none of the sites at all in 2019 showed a correlation between dissolved oxygen and water temperature.

In 2017, at the Kennelworth, Manorhaven, NUN-4, Baxter Beach, and Manorhaven Beach sites and in 2019 at all sites, there was no correlation between dissolved oxygen and rainfall. However, in 2017, at the Leeds Pond and Great Neck sites, dissolved oxygen was shown to have a positive correlation ($p > 0.70$) with rainfall that occurred two days prior to sampling. This means that DO increased two days after a rainfall. This can be explained as rainfall carries nutrients to the water, which increases photosynthesis, thus raising dissolved oxygen. What the data is not picking up is what happens after a bloom of algae,

[26] https://coalitiontosavehempsteadharbor.org/waterquality-reports

when those algae are decomposed by bacteria. This signal would show up in bottom dissolved oxygen levels, but this was not measured.

4.d Is there a spatial difference in bacteria concentrations within the bay?

On a bay such as Manhassest Bay, where one area of the watershed is highly developed and another is not, there are specific spatial trends that are expected:

- Where the watershed is more densely populated (northeastern and southern portions of the Bay), higher bacteria are expected, especially after a rainfall, as this area does not have a lot of natural habitat, but instead has lots of roads, buildings, and storm drains.
- Where the watershed is less densely populated and, therefore, there is more plant life (northwestern portions of the Bay), lower bacteria counts are expected as compared to the eastern Bay.
- The same is true of the central bay, where water is flushed with Long Island Sound.

The spatial differences between sites in 2017, 2018, 2019, and 2020 fits what would be expected, with lower bacteria counts in the western and central Bay as compared to the eastern Bay. This does not follow in 2016, with the second highest mean concentration for the summer being at MB-2 (Kennelworth), which is on the western edge of the Bay where there is less dense development and more flushing with Long Island Sound. Additionally, Leeds Pond (MB-1), which is in the less densely populated central-eastern Bay, had the highest rolling geometric mean and is the only station to have exceeded the standard in 2016. Additionally, later summer 2021 saw Leeds Pond (MB-1) and Kennelworth (MB-2) experience the highest Enterococci geometric means. Conversely, Great Neck (MB-7), a site expected to have the highest bacteria counts due to its location in the narrow and shallow back portion of the Bay, was among the lowest for the entire summer.

5 Conclusion

The data presented here did not indicate that a distinct "the bay is safe for swimming" statement could be made. It can be said that the Bay is not safe for swimming during or directly after a rainstorm.

Watershed municipalities face tough regulations since the Bay does not meet water quality standards. Additionally, new research has demonstrated that climate change will compound water quality issues. A new Water Quality Improvement Plan[27] is in development at the time of this report writing. Recommendations that emerge from that plan will put an onus on government and private individuals alike to change behaviors, implement programs and projects, and change laws and zoning to achieve water quality goals. These recommendations may be difficult to consider, but they must be supported in order to improve water quality. It is recommended that these watershed municipalities and their partners and citizens recognize the need for improving water quality and rally behind the Plan's findings while also continuing already established programs. Water quality goals will be slow to reach, but reports such as this one will highlight these achievements and, thus, the importance of watershed-wide changes.

[27] More information can be found at ManhassetBay.net or, specifically, at manhassetbayprotectioncommittee.org/wqip.html

6 List of Appendices

Appendix A. Bacteria counts and site conditions by year and station supplied by the Nassau County Department of Health

Appendix B. Water quality parameters

Appendix C. Summary of daily weather data from NOAA's LaGuardia Airport weather station

Appendix D. Bacteria data v. applicable State standards

Appendix E. Tables of correlations between annual rainfall data

Appendix F. Tables of correlations between bacteria counts and rainfall

Appendix G. 2022 Water Quality Sampling and Analysis

Appendix G-1. 2022 bacteria counts and site conditions by date and station supplied by the Nassau County Department of Health