Comparison of Enterococci Water Quality Data Sets Taken In Coney Island Creek, Brooklyn

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Abstract

There is a current renaissance of interest in urban waterways. This interest includes restoring and remediating these formerly neglected and degraded "blue" spaces for a variety of ecological and human needs. The Coney Island Creek is one such urban waterway, located in southern Brooklyn, NY. Both the New York City Department of Environmental Protection and a volunteer, citizen-based NYC Water Trail Association, collect water samples within the Creek for fecal indicator bacterial analyses. Aside from an initial study in 2016 to validate the different analysis test kits employed by those groups in providing similar enterococci bacteria results, no known further study has been attempted to compare DEP and Water Trail Association data sets. This study attempted to analyze several years of matching months of sample data at geographically related sampling sites, with t-test scores showing significant differences in results. Several reasons for the differences seen, including lack of consideration of rainfall events, are discussed. Finally, the results of this study will be shared with organizations dedicated to Creek stewardship to promote further practical aims.

Introduction

Harbors, inland waterways, and wetlands have been critical conduits for human settlement and use. Indeed, along with permanent settlements and agriculture, the development of cities and urban centers in the ancient world relied on access to natural waterways and later the ability to control and direct their flow for human needs (Mays, Koutsoyiannis & Angelakis, 2007). This was no less true, in recent centuries, for the less-developed past of today's modern metropolises.

The five boroughs of modern New York City form one such metropolis born from a similar evolution. "Blessed with deepwaters offshore," multiple ponds to provide freshwater, and abundant aquatic wildlife to provide food, this harbor region was attractive for both native inhabitants and European newcomers alike (Sanderson, 2013). Even around the time of the American Revolution, New York City's Manhattan island contained a stream network of 67 miles in total length (Sanderson & Brown, 2007).

The inland creeks and watersheds in the outer borough of Brooklyn (incorporated into New York City in 1898) were also an attraction for settlement and agriculture as well as a driver of industry. Starting in the 1600s, settlers harvested oysters, established farms, and built tide mills along the Gowanus Creek watershed to process flour, which could then be shipped directly out via the Creek (Alexiou, 2015). At the southern end of Brooklyn, along the waterway and marshes of Coney Island Creek, native fishing and shell gathering gave way to European cattle grazing on *Spartina patens,* or "salt hay," an important crop from which settlers also extracted salt for human use (Mather, 1843; Denson, 2002).

Over the next several hundred years, the impressive industrialization and urbanization of the city harmed those very same waterways from which the city in part grew. Oil refineries along the shore of Newtown Creek leached byproducts and chemicals that continue to plague the waterway to this day (Prud'homme, 2010). Gowanus Creek was expanded into a canal for shipping and industry that, along with combined sewer overflow (a remnant feature of the city's infrastructure where untreated household sewage gets mixed with rainwater), gave it a city-wide notoriety for contamination and toxicity (Alexiou, 2015; Enman, 2019). Both sites are now EPA superfund sites. Coney Island Creek has suffered a long history of degradation and neglect, as well, from local gas company pollution, combined sewer overflow, and illegal dumping (Denson, 2015; Fetters, 2018; McShane, 2018).

Yet we are currently in a renaissance of rediscovery of urban waterways. Cities around the world, from Paris to Chicago and Mexico City to Seoul, have, or are developing, restoration projects of these formerly neglected "blue" spaces for environmental resiliency, ecosystem services, social purposes, and human health and recreation (Chicago Council on Global Affairs, City of Chicago, City of Paris, & World Business Chicago, 2017). Locally, organizations such as the Gowanus Canal Conservancy and Gowanus Dredgers have focused on the Gowanus Canal, while the Coney Island Beautification Project, Coney Island History Project, and NY Aquarium, among several others, have focused on Coney Island Creek (Making Waves Coalition, 2018; McShane, 2018).

Towards these aims of remediation and renewed use, the accuracy and public accessibility of water quality data is important for human health and awareness. The NYC

Department of Environmental Protection (hereafter "NYC DEP") conducts water quality testing in local waters. Independent non-profit groups, however, have also taken a lead in promoting citizen science data to build a larger set of data and make it more publicly accessible (Farnham et al., 2017; New York City Water Trail Association, n.d.a.). During the summer of 2018, I volunteered with the NYC Water Trail Association (hereafter "NYC WTA"), an organization that relies on a network of volunteers to conduct water quality testing around New York City waters to better inform recreational users (New York City Water Trail Association, n.d.a.). I assisted with collecting water samples from Coney Island Creek, then transporting those samples to a microbial research lab at Brooklyn College for analysis.

Farnham et al. (2017) conducted prior data comparison of different water testing methods employed by NYC DEP and by NYC WTA . That study provided evidence for the validity of multiple kinds of test kit approaches and citizen-acquired data. However, that study took place in 2016, at the start of NYC WTA's citizen's water quality testing program (CWQT). Now, more than three years of data have accumulated, and there has been no continuous, systematic study comparing NYC DEP and NYC WTA data sets. Additionally, Farnham et al. (2017) did not examine data from Coney Island Creek, where the aforementioned attention is now shifting. I inquired about both of these points with Rob Buchanan, co-founder of NYC WTA, who said: "we've done spot comparisons but nothing systematic" (personal communication, September 27, 2019).

This inquiry examines and compares existing water quality data sets between NYC DEP monitoring data and citizen-based NYC Water Trail Association data, taken at Coney Island Creek (See Appendix A – Map), focusing specifically on bacterial enterococci results. I predict that there will be no significant difference in results, due to prior methodology comparison between those groups (Farnham et al., 2017). This comparison and its results could contribute to ongoing validity or improvement of these combined efforts, both for public water safety and continued stewardship and remediation of the Coney Island Creek.

Methods

Both NYC DEP and the volunteer-based NYC WTA provide online water sampling data for New York City. I found the DEP data set—"Harbor Water Quality"—within New York City's free repository of city data (NYC Open Data, 2019). At the time of this study, the entire Harbor Water Quality data set contained 88,000+ rows of data from various sampling sites and dates. One hundred columns outlined the various kinds of data parameters taken—from water temperature, dissolved oxygen, and pH to fecal coliform and enterococci bacteria levels. For this study, I accessed enterococci data ("Top Enterococci Bacteria – Cells/100mL") for the Coney Island Creek DEP sampling locations**.** Enterococci levels are a standard measure of "Fecal Indicator Bacteria," used as an analog to indicate the presence of other harmful bacteria and pathogens in water samples (Byappanahalli, Nevers, Korajkic, Staley, & Harwood, 2012). The timeframe of the data set represented samples taken beginning in 2010 up to 2019.

It's worth noting that some trial and error was involved in accessing my desired subset of data from the 88,000+ rows, if others intend to replicate a similar procedure. Initially, I attempted to use web-based data feeds from Harbor Water Quality that would auto-populate an Excel or Google Sheet spreadsheet, which I then planned to filter to retrieve only the Coney Island Creek DEP sampling locations. Various incompatibility or complexity issues made these attempts too time-consuming.

Instead, from the Harbor Water Quality web page, I clicked on the button "View Data," and on the resulting page, I entered "CIC2," "CIC2W," and "CIC3" respectively in the "Find in this Dataset" search field and then exported comma-separated value (.csv) files of each of those search results (a PDF map on the Harbor Water Quality web page identified "CIC2" and "CIC3" as the codes for Coney Island Creek sampling locations. "CIC2W" is apparently an alternate location for "CIC2" that I only noticed when browsing the full data set. I had to search for the exact "CIC2W" term to retrieve this information).

I took the exported .csv files of data and imported and collated them into a Google Sheets spreadsheet, sorting by sampling location and sampling date. The result formed my collated, DEP raw data spreadsheet.

From the online NYC Water Trail Association Data (New York City Water Trail Association, n.d.b.), I pulled 2016-2019 enterococci data for Coney Island Creek. Through an interactive Google Map, users can click on a sampling location and a pop-up window provides links to Google Drive spreadsheets for each of those years. As shown in Appendix A – Map, there are four NYC WTA sampling sites along Coney Island Creek: Kaiser Park Beach, West 21st St., Shell Road, and Calvert Vaux Park Boat Launch. Although users can theoretically add each of those spreadsheets direct to their own Google Drive account, I instead exported Microsoft Excel versions. In this case, I then imported/collated the spreadsheet data for the two NYC WTA sampling sites closest to the NYC DEP sampling sites. These were Kaiser Park Beach and West 21st St. I sorted their data by sampling location and date, and matched the overall format I had previously set up for the NYC DEP data. The result formed my collated, NYC WTA raw data spreadsheet.

Finally, I rearranged the data into spreadsheets comparing and analyzing summary data for the set of closest sampling sites *between* NYC DEP and NYC WTA data—a data analysis spreadsheet for DEP CIC2(+W) and WTA W. 21st St. and a data analysis spreadsheet for DEP CIC3 and WTA Kaiser Park. By using named ranges to summarize the data per each month samples were taken, I made tables comparing the number of samples taken at each site per month, the average enterococci count (in Cells/100mL) per month, the median enterococci count (in Cells/100mL) per month, along with range scores per month and Student's t-test analysis of each total range of data. For months where data did not match up (e.g., if the NYC WTA sampled in May 2017 and NYC DEP did not, I removed these months from range and t-test analysis.

Results

Table 1 below shows summarized results for NYC DEP sampling site CIC2 (plus it's alternate site 2W) and the NYC WTA sampling site at W. 21St. St.

Selected Matched Months	NYC DEP # of samples	NYC DEP average ent. cells/100mL	NYC DEP +/- average	NYC DEP median ent. cells/100mL	NYC WTA # of samples	NYC WTA average ent. cells/100mL	NYC WTA +/- average	NYC WTA median ent. cells/100mL
Aug 2016	10	1,148	2,367	40	4	468	879	43

Sep 2016	7	162	123	152	5	393	292	449
Jun 2017	8	191	148	180	5	319	364	213
Aug 2017	8	160	166	100	5	317	388	118
Sep 2017	7	630	1,220	175	4	516	557	320
May 2018	2	1,338	371	1,338	2	4,611	n/a	4,611
Aug 2018	5	192	242	30	5	1,232	1,293	935
Sep 2018	2	1,364	1,889	1,364	4	8,441	456	8,704
May 2019	2	225	290	225	2	4,031	5,494	4,031
Jun 2019	2	10,036	14,091	10,036	4	7,281	10,896	1,022
Jul 2019	2	128	n/a	128	3	8,210	8,664	7,215

Table 1
Comparison table of NYC DEP sampling site CIC2 (+2W) and volunteer collected NYC WTA date from the W. 21st. St. sampling site.

Using the data in Table 1, Student's t-test scores were calculated with the built-in t-test function in Google Sheets. The results, listed in Table 2, highlight that there is a significant difference between the NYC DEP and NYC WTA data sets, which rejects my assumption that there would be no significant difference between the data sets.

Student's T.Test b/w NYC DEP & NYC WTA	Result
Average	0.19
Median	0.34

Table 2
Student's T.Test results between NYC DEP CIC2 (+2W) and NYC WTA W. 21st St.sampling sites.

Table 3 below shows summarized results for NYC DEP sampling site CIC3 and the closest NYC WTA sampling site at Kaiser Beach Park.

Selected Matched Months	**NYC DEP # of samples**	**NYC DEP average ent. cells/100mL**	**NYC DEP +/- average**	**NYC DEP median ent. cells/100mL**	**NYC WTA # of samples**	**NYC WTA average ent. cells/100mL**	**NYC WTA +/- average**	**NYC WTA median ent. cells/100mL**
Sep 2016	4	19	12	20	5	42	36	41
Jun 2017	10	109	154	11	5	259	235	191
Jul 2017	4	7	4	7	4	970	1,395	375
Aug 2017	10	55	70	23	5	121	198	31

Sep 2017	5	11	16	3	4	131	116	127
May 2018	5	11	16	3	2	135	n/a	135
Jun 2018	4	24	27	13	4	863	552	771
Jul 2018	2	16	13	16	4	466	471	290
Aug 2018	2	1,431	7,539	11	5	1,474	2,499	448
Sep 2018	3	198	186	160	4	5,665	4,992	6,270
Jul 2019	2	2	1	2	3	9,310	13,025	3,724

Table 3
Comparison table of NYC DEP sampling site CIC3 and volunteer collected NYC WTA date from the Kaiser Beach Park sampling site.

Again, using summarized data, this time in Table 3, Student's t-test scores were calculated with the built-in t-test function in Google Sheets. The results, listed in Table 4, highlight that there is a significant difference between the NYC DEP and NYC WTA data sets for this second set of sampling sites as well. These t-test scores, although lower than the first set of compared sampling sites, still reject my assumption that there would be no significant difference between the data sets.

Student's T.Test b/w NYC DEP & NYC WTA	Result
Average	0.11
Median	0.10

Table 4
Student's T.Test results between NYC DEP CIC3 and NYC WTA Kaiser Beach Park sampling sites.

I attempted further comparison of the data sets to visually understand the apparent differences. Figures 1 and 2 below graph the median enterococci counts per matching month between the NYC DEP and NYC WTA data sets that I examined. Each graph illustrates a striking visual disparity between data sets.

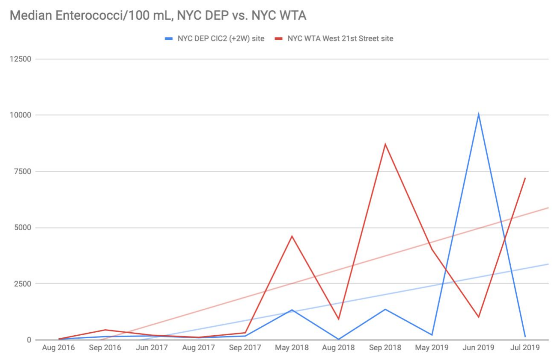

Figure 1
Comparison of median enterococci counts (per 100/mL) per matching month between NYC DEP CIC2 (+2W) and NYC WTA W. 21st. St.data, with trendlines.

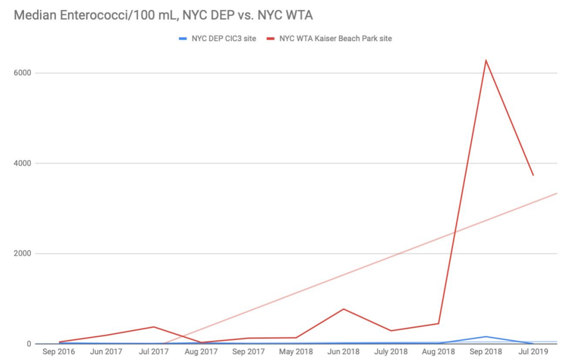

Figure 2
Comparison of median enterococci counts (per 100/mL) per matching month between NYC DEP CIC2 (+2W) and NYC WTA W. 21st. St.data, with trendlines

Discussion

There could be a number of reasons that the anticipated results were not seen. This was my first foray into this kind of data comparison and I am not certain if I used the correct data analysis techniques to properly analyze the data. That said, the range of results in every case was quite high regardless.

Other issues that may have affected the outcomes include the fact that sampling sites between the agencies studied here are not exactly in the same location and it's possible that results are skewed by differences in specific location, depth, and the micro-environmental conditions at each site.

Furthermore, sampling between the agencies represented here are not conducted on the same exact days or times. A higher resolution of examination, perhaps one looking at the most closely related collection dates instead of collated monthly data, could have proved useful. Related to water sampling dates, bacterial results can be dependent on rainfall prior to sampling (Byappanahalli, Nevers, Korajkic, Staley, & Harwood, 2012; Farnham & Lall, 2015; Farnham, et al., 2017). This is likely due in part to the combined sewer overflow systems that combined untreated sewage and rainwater, and also in part to surface runoff conditions, which additionally bring contaminants into the Creek system.

Methods to account for the variation in results due to rainfall were discussed in Farnham, et al. (2017), the earlier paper I cited, and are further examined in (Farnham & Lall, 2015). However, I was unable to refine my methods further due to time and family constraints.

Action Component

A main aim of this project is to follow up with an action component to develop practical use of my findings. Specifically, my goal will be to share the findings of this report (or a further revision of it) with organizations currently working to protect and restore the Creek.

During the course of this project, I was in touch with several individuals and organizations to whom this study could prove useful. I reached out to Noah Chesnin, associate director of the NY Seascape Program at the New York Aquarium, early on with ideas for an inquiry and action study, asking which of my ideas would be useful to his team. One of their responses highlighted the water quality analysis that I conducted in this paper as one of interest (personal communication, September 23, 2019). I also reached out to Rob Buchanan of NYC WTA with the same suggestion of this study, who said: “could be a cool project!” (personal communication, September 27, 2019).

Additionally, because advocacy and stewardship of the Coney Island Creek are a master plan focus of my Advanced Inquiry Program graduate study, I have also come into direct contact with Pamela Pettyjohn at the Coney Island Beautification Project and Charles Denson at the Coney Island History Project. I will share this report (or again, a further revision of it) by email with Noah, Rob, Pamela, and Charles. Collectively, they form a constituency concerned with the health and remediation of the Coney Island Creek. The results of this report could potentially inform decisions they are currently making about a Coney Island Creek conservancy group, or perhaps help indicate the need for further grant funding regarding water quality analysis, or the continued clean up of the Creek through stewardship and city programs.

One current city-guided effort is to bring ferry service to the Coney Island Creek to aid residents’ work commutes and give visitors another method of coming to Coney Island’s historic amusement areas (McShane, 2019). However, not all residents approve of this decision due in part to environmental concerns (McShane, 2019). Again, findings that concern the water quality and safety of the Creek might be relevant to those planning or working around the Creek if ferry service is to come, not to mention local residents who still fish and crab within the Creek.

Finally, an additional use of this report could concern education efforts. This past summer, I co-led a high school ecology class called the Urban Naturalists Program, which was developed by the NY Aquarium with grant funds derived from fines assessed to buildings illegally dumping into the Creek (McShane, 2018). During this class, some students chose to test for water quality. Perhaps my study could serve as a reference point for further study. Other organizations like the City Parks Foundation hold “coastal classroom” activities along the Creek during the summer months. In both cases, I could share my results with these groups as well, not only as it may relate to their curriculum, but also to the health and safety of their students.

Conclusion

In this study, I attempted to compare critical water quality data sets relevant to the Coney Island Creek. Though my assumptions that there would be no significant difference between the data sets was not proven, there still remains a new public interest in restoring urban waterways. Brooklyn, NY shouldn’t be without the restoration of these amenities, both for the sake of the natural ecosystem and its wildlife, and for human pride and enjoyment. Like the Gowanus Canal and Newtown Creek before, I hope that the Coney Island Creek continues along a path of remediation and continued stewardship. Hopefully, my study is the start of future endeavors that I can bring to that purpose.

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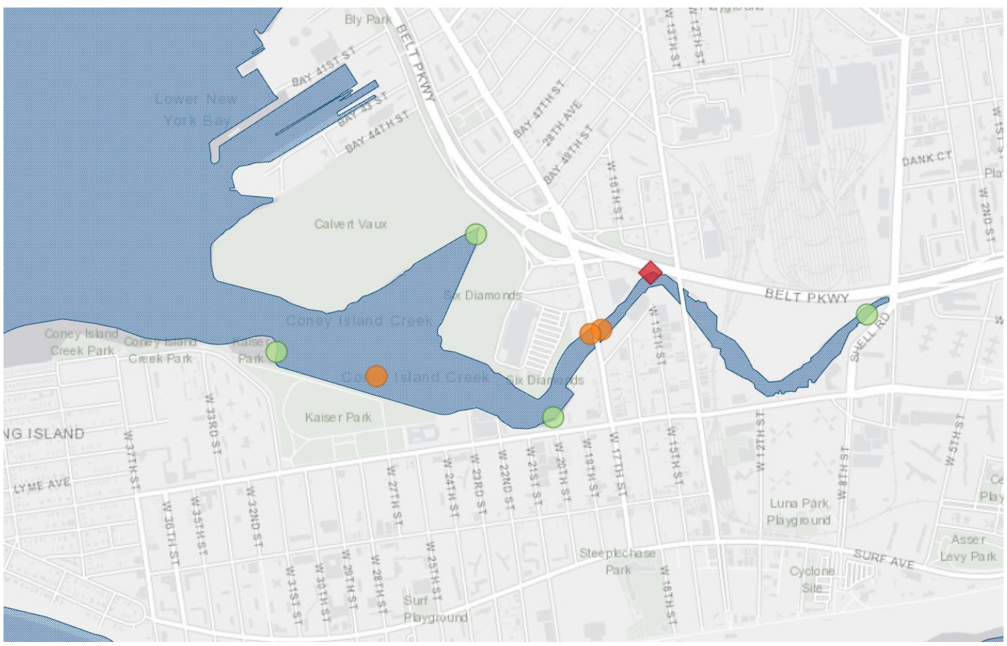
Appendix A – Map

New York City (left). Area of interest in southern Brooklyn (right).
Closeup of area of interest is below.



Coney Island Creek, Brooklyn, NY, with highlighted sampling
sites and combined sewer overflow outfall.

Key/Legend

- Combined Sewer Overflow (CSO)
- NYC DEP sampling locations
- NYC WTA sampling locations

Maps generated in QGis with data from:

- ESRI (basemap)
- NYC Geodatabase (borough boundaries)
- NYC DEP (sampling sites, coordinates via Google Maps)
- NYC WTA (sampling sites, coordinates via Google Maps)
- Open Sewer Atlas (CSO location coordinates)