All That Garbage in the Water: Effect of Water Pollution on the Microbiomes of New York City's Water Bodies

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Abstract

The accumulation of various forms of pollution in the Gowanus Canal have impacted the dynamics and composition of microbiomes (microorganisms vital to the functions of the hosts and/or systems they inhabit). Identifying the composition and dynamics of urban microbiomes is essential to understanding the management of microbes in a manner that contributes to urban sustainability. Thus, the purpose of this project is to investigate the effects of pollution on the microbiomes of New York City's water bodies. To conduct our research, water samples from different parts of the Gowanus Canal was gathered. DNA extraction was later used, and the PCR was useful for the amplification of the DNA, which later underwent 16s rRNA

sequencing. To analyze the composition of bacteria within each sample, bioinformatics was used to generate taxonomic assignments and run beta diversity tests.

References

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Introduction

The Gowanus Canal is infamous for being one of the most contaminated water bodies in the nation. However, despite the severity of its contamination, the Gowanus Canal still serves as a home to various microorganisms that sustain their life while fulfilling important roles in the community. Microorganisms existing in complex communities, called microbiomes, have a significant role in the functions of the hosts and/or systems that they inhabit. However, the dynamics and composition of microbiomes, as well as the services that they provide to urban life, are sensitive to disposal of excess wastewater into water bodies. Identifying the composition and dynamics of urban microbiomes is essential to understanding how to manage microbes in a way that contributes to urban sustainability. This project's purpose consists of investigating the effects of pollution on the microbiomes of New York City's water bodies.

We hypothesized that if the microbiomes from a polluted and relatively less polluted water source are compared, then the species composition will be vastly different because of the laws of natural selection. In accordance with the situation of the Gowanus Canal, if a gene pool is significantly altered by the introduction of new microbes and there are cataclysmic abiotic and biotic changes to the ecosystem, then there will be a selection for microorganisms best capable in exploiting the resources around them.

Materials & Methods

Samples from locations A and B were collected using a jug tied to a rope, which was used to collect mainly surface water, whereas the method of collection was changed for location C using a more advanced water sampling device that collected samples at a specific depth only. Due to this change and the nature of the Gowanus Canal, it was difficult to standardize the filtered volumes. DNA extraction was conducted using the DNeasy Blood and Tissue Kit, a method suggested by a research paper on maximizing recovery of eDNA from water samples. Subsequent gel results showed a problem in which no DNA was harnessed and reruns of the experimental setup which included changing the PCR protocols revealed that the flaw was not due to faulty replication but due to the extraction kit being expired. Thus, after reordering the extraction kit, the gel results showed DNA yield but it was minimal so we ran our samples through a spin-vacuum and reran the PCR using 50 cycles instead of 25.

Results

Especially within marine environments having extreme conditions, the rate at which bacteria evolve to uniquely adapt to the environment is rapid which points to a trend in which their metabolism incorporates the environment's deadly toxins. This is a trend we noticed in our results, in which these bacterial species have characteristics of being able to consume the Gowanus Canal pollutants. When comparing the changes in abiotic factors throughout the Gowanus Canal to the relative abundance of species in each sample, we noticed the following trends:

1. Proximity to outfall and correlation to abiotic factors: The farther away from the CSO outfalls (the release of waste from the pipes, see Diagram A), there is generally lower dissolved oxygen levels and lower pH levels as interpreted from Diagram B.
2. Archaea: The presence of Methanobacteria and Methanomicrobia species that produce methane as a metabolic byproduct in anoxic conditions suggests adaptation to an anaerobic environment as they also remove excess hydrogen and fermentation products produced by anaerobic respiration, acting in symbiosis with other anaerobic microorganisms.
3. Bacteria: There are many instances of the characteristics of bacterial species aligning to the Gowanus Canal's characteristics:
   - Acidobacteria survive in acidic environment and are thus likely to be found farther away from the outfalls where pH is lower
   - Actinobacteria and Bacteroidetes are decomposers of organic matter and especially thrive in an environment like the Gowanus Canal containing a high volume of waste.
   - The prevalent presence of extremophiles like Deinococcus-thermus which is highly resistant to environmental hazards, Firmicutes which produces endospores resistant to desiccation, and Thermotogae which are thermophilic suggest that microorganisms are adapted to the extreme conditions of the Gowanus Canal. Many of these species have their own metabolism mechanisms that capitalize on existing molecules within the Canal. For example, the Deinococcus-thermus degrade and metabolize sugars and polymeric sugars, some Actinobacteria and Proteobacteria can fix nitrogen, and Thermotogae are able to use complex carbohydrates to produce hydrogen gas.

Discussion

Especially within marine environments having extreme conditions, the rate at which bacteria evolve to uniquely adapt to the environment is rapid which points to a trend in which their metabolism incorporates the environment's deadly toxins. This is a trend apparent in our results, in which these bacterial species have characteristics particularly adapted to the Gowanus Canal's abiotic conditions - thus affirming our hypothesis. Not only can the potential discovery of these bioremediating bacteria have enormous uses to deal with current environmental challenges but can also provide new insight on whether or not pollution in the Gowanus Canal affects nearby habitats farther away from the outfall pipes and how one can approach the cleanup of the Gowanus Canal while keeping in mind the dynamics between microorganisms. A potential avenue of future research would be to examine the interactions between the microbiome of extremely polluted waterways like the Gowanus Canal and that of nearby water sources and deltas such as the Hudson River in an effort to further investigate the dynamics of urban microbiomes. In addition, the organisms sequenced may be extended to invertebrates if the trend of adaptation extends further.

Table and Figures

Table 1: Sample Metadata

Samples	Filtered Volume	Depth	Coordinates	Proximity Ranges from CSO Outfall
A	250 mL	surface	-73.989186 40.678051	0-10 meters
B	250 mL	surface	-73.990345 40.676016	10-50 meters
C1	25 mL	3.05 meters	-74.002286 40.668343	50+ meters
C2	25 mL	2.80 meters	-74.002286 40.668343	50+ meters
C3	10 mL	1.7 meters	-74.002286 40.668343	50+ meters