

Prepared in cooperation with the New York State Department of Environmental Conservation

Using Microbial Source Tracking To Identify Contamination Sources in Port Jefferson Harbor, Setauket Harbor, and Conscience Bay on Long Island, New York



Scientific Investigations Report 2021–5141

Cover. Culvert discharging into Scotts Cove in Setauket Harbor at Setauket-East Setauket, New York, viewed looking north from Shore Road during a sampling trip; photograph by Tristen Tagliaferri, U.S. Geological Survey.

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By Tristen N. Tagliaferri, Shawn C. Fisher, Christopher M. Kephart, Natalie Cheung, Ariel P. Reed, and Robert J. Welk

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Contents

Acknowledgments	iii
Executive Summary	1
Introduction.....	2
Site Description.....	2
Approach and Methods	5
Results	5
Microbial Source Tracking	5
Host Specific Markers	6
HF183.....	6
BacCan	8
GFD	10
Fecal Coliform Bacteria	11
Nonpoint Sources of Fecal Coliform Bacteria	13
Classification of Source Sites.....	13
Culvert North of State Route 25A—Class 1	13
Culvert North of Shore Road—Class 1	13
Mill Pond Culvert to Conscience Bay—Class 1	16
Old Mill Creek Culvert—Class 1	16
Outfall Near Danfords Marina—Class 3.....	16
Sewage Treatment Plant Outfall—Class 5	16
Sediment—Class 5	16
Groundwater—Class 5.....	17
Summary.....	17
References Cited.....	17
Appendix 1. Sample Collection at Port Jefferson and Setauket Harbors on Long Island, New York.....	19
Appendix 2. Sample Collection in Conscience Bay on Long Island, New York	24

Figures

1. Map showing the extent of the priority waterbodies in the Port Jefferson Harbor complex on Long Island, New York	3
2. Map showing locations where surface-water (blue), groundwater (green), and sediment (red) samples were collected by the U.S. Geological Survey for microbial source tracking in the Port Jefferson Harbor complex on Long Island, New York	4
3. Graphs showing concentrations of the human <i>Bacteroides</i> marker in Port Jefferson Harbor and Setauket Harbor on Long Island, New York.....	7
4. Graphs showing concentrations of the human <i>Bacteroides</i> marker in Conscience Bay on Long Island, New York.....	8
5. Graphs showing concentrations of canine <i>Bacteroides</i> marker in Port Jefferson Harbor and Setauket Harbor on Long Island, New York.....	9
6. Graphs showing concentrations of canine <i>Bacteroides</i> marker in Conscience Bay on Long Island, New York.....	10

7. Graphs showing concentrations of waterfowl *Helicobacter* marker in Port Jefferson Harbor and Setauket Harbor on Long Island, New York.....11

8. Graphs showing concentrations of waterfowl *Helicobacter* marker in Conscience Bay on Long Island, New York.....12

Tables

1. Summary of microbial source tracking results in surface-water samples for sites sampled in Port Jefferson Harbor, Setauket Harbor, and Conscience Bay on Long Island, New York.....6

2. Geographical sources of water for sample locations and the potential for these sites to have contributed to the fecal coliform concentrations observed in the samples.....14

3. Sample results for fecal coliform and microbial source tracking markers by source site type at Port Jefferson Harbor, Setauket Harbor, and Conscience Bay on Long Island, New York.....15

Supplemental Information

Concentrations of fecal coliform bacteria are given in most probable number per 100 milliliters (MPN/100 mL).

Concentrations of microbial source tracking markers are given in marker copies per 100 milliliters (copies/100 mL).

Abbreviations

BacCan	canine-associated <i>Bacteroides</i> marker
FC	fecal coliform bacteria
GFD	waterfowl-associated <i>Helicobacter</i> marker
HF183	human-associated <i>Bacteroides</i> marker
MPN	most probable number
MST	microbial source tracking
NWIS	National Water Information System
NYSDEC	New York State Department of Environmental Conservation
Rum2Bac	ruminant-associated <i>Bacteroides</i> marker
USGS	U.S. Geological Survey

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Executive Summary

The U.S. Geological Survey worked collaboratively with the New York State Department of Environmental Conservation to assess the potential sources of fecal contamination entering seven estuarine embayments across Long Island, New York, from June 2018 to July 2019. Water samples are routinely collected by the New York State Department of Environmental Conservation in Long Island embayments and analyzed for fecal coliform bacteria, an indicator of fecal contamination, to determine the closure of shellfish beds for harvest and consumption. Concentrations of fecal coliform signify the potential for pathogenic (disease-causing) bacteria to be present.

Indicator bacteria alone cannot determine the biological or geographical sources of contamination. Microbial source tracking is a method used to determine these sources of contamination. Microbial source tracking laboratory techniques can ascertain whether genetic material obtained from *Bacteroides* or *Helicobacter* bacteria in water or sediment is consistent with humans, canines (dogs), ruminants (deer, sheep), or waterfowl. *Bacteroides* and *Helicobacter* are genera of bacteria found in the gut of most warm-blooded animals. These techniques can also quantify the concentration of genetic markers found.

Information such as sample location, weather, and season, surrounding land use, and additional water-quality data help determine the geographical source and conveyance of land-based water to the embayment. The presence of genetic material and fecal coliform bacteria in samples collected at the same time is important to show that the fecal coliform bacteria are likely from the host source detected. It is possible for waters with waste infiltration to have genetic material present but no fecal indicators, such as disinfected water from a sewage treatment plant or from groundwater that has passed through a sandy aquifer.

Water samples were collected in the summer and winter seasons. In each of the two seasons, one sample was collected in dry weather, and one, after substantial rainfall. Groundwater and sediment samples were also collected throughout the

study. Surface-water source sites sampled for Port Jefferson Harbor and Setauket Harbor include the culvert north of State Route 25A, the culvert north of Shore Road, the Old Mill Creek culvert, the outfall near Danfords Marina, and the Port Jefferson sewage treatment plant. The Mill Pond culvert was sampled as a surface water source site for Conscience Bay.

Human, canine, and waterfowl fecal contributions to the Port Jefferson Harbor complex were frequently detected across the landscape. Among the potential sources of fecal contaminated water contributing to the Port Jefferson Harbor complex—groundwater, pond and wetland drainage, stormwater, marinas (boats), and the Port Jefferson sewage treatment plant—pond and wetland drainage and stormwater from municipal separate storm sewer system conveyances were found to be the most likely transport mechanism of fecal contamination.

The most substantial source of fecal contamination to the Port Jefferson Harbor complex was found to be from sites draining ponds and wetlands, particularly during the summer season with higher concentrations of fecal coliform bacteria in wet weather. These sites include the culvert north of Shore Road, the culvert north of State Route 25A, Old Mill Creek, and Mill Pond to Conscience Bay. Discharge from the single stormwater outfall sample (outfall at Danfords Marina) was also a substantial contributor of fecal coliform bacteria. Contributions of fecal contamination did not appear to be attributable to the Port Jefferson sewage treatment plant or to boats and marinas in Port Jefferson Harbor. While the microbial source tracking results indicated influence from septic systems, it has not been shown that groundwater contributes to fecal coliform bacteria loads. One of the two groundwater samples along the shoreline of Port Jefferson Harbor where microbial source tracking analyses were conducted showed evidence of human and waterfowl waste that did not have corresponding fecal coliform bacteria detections, indicating limited transport of bacteria in the subsurface groundwater through the sandy aquifer material, which is consistent with results throughout Long Island. Sediment sampled along with the groundwater sample at the Public Beach and Dog Park is

unlikely to act as a source during resuspension events, such as an ebbing (outgoing) tide, storm-driven waves (particularly at low tide), and boat wakes.

A classification scheme was developed that considered conditions such as high fecal coliform bacteria concentrations (particularly during dry weather samples) and contributions from human and canine waste based on detection of microbial source tracking markers. The class of sites were assessed to assist stakeholders and resource managers in prioritizing which source sites are consistently contributing fecal coliform bacteria to the Port Jefferson Harbor complex throughout the year. The culvert north of State Route 25A, the culvert north of Shore Road, the Old Mill Creek culvert, the outfall near Danfords Marina (only one sample collected), and the Mill Pond culvert to Conscience Bay were classified as locations that contribute substantial fecal contamination to the Port Jefferson Harbor complex.

Introduction

To better understand fecal contamination sources in coastal embayments on Long Island, microbial source tracking (MST) and fecal coliform bacteria (FC) data were collected from seven embayments from June 2018 to July 2019 (U.S. Geological Survey, 2020a). The objective of this research is to identify the different pathogen sources, both the host organism (such as human, mammals, or birds) and geographic origin (such as urban and storm runoff or submarine groundwater discharge), to embayments with fecal contamination. The embayments selected represent a mix of sewer and unsewered areas, differing levels of impervious land cover, varying population density, and a variety of land-use types so as to transfer what is learned to other areas beyond the seven studied. In total, 353 samples were collected in the seven embayments on Long Island. These were primarily surface-water samples but also included 17 groundwater, 11 sediment, 2 sewage influent, and 8 fecal samples.

The presence of fecal contamination in the Port Jefferson Harbor complex and resulting hazards posed to marine resources and human health are of increasing concern. Recreational uses of the harbor, including shellfishing and public bathing, are frequently restricted due to high counts of FC, which are used as surrogate indicators for when pathogens may be present. Pathogen loads can be influenced by watershed land use, proximity to point sources such as municipal separate storm sewer systems, as well as tidal exchange and circulation transporting pathogens from outside the study area (Gao and others, 2015), sediment resuspension (O'Mullan and others, 2019), and human recreation (including boating). Sewage treatment plants can also act as point sources (through effluent discharge) for pathogens when standard operations and procedures for disinfection are compromised. Nonpoint sources may include shallow groundwater discharge because many of the areas surrounding the Port Jefferson Harbor

complex still rely on onsite wastewater disposal systems, such as cesspools and septic systems. Through routine FC monitoring, the New York State Department of Environmental Conservation (NYSDEC) has identified fecal contamination as a concern in the Port Jefferson Harbor complex. Microbial source tracking techniques are necessary to determine the dominant source (human, canine, ruminant, waterfowl) and geographic origin of FC, using land use, topography, and hydrology to establish a framework. The success of future pathogen-control measures may be measured by the decline in FC concentrations.

Site Description

The Port Jefferson Harbor complex is an interconnected system of embayments that include Port Jefferson Harbor, Setauket Harbor, Little Bay, the Narrows, and Conscience Bay (fig. 1). These embayments are connected to Long Island Sound by a single inlet on the northern end of Port Jefferson Harbor in the town of Brookhaven, Suffolk County, New York. Port Jefferson Harbor is bordered by the villages of Belle Terre to the east, Port Jefferson to the south, and Poquott to the west. Setauket Harbor is bordered by Poquott to the northeast and Setauket-East Setauket to the south and west. Conscience Bay is bordered by Setauket-East Setauket to the east and the village of Old Field to the west. Strongs Neck is a dividing peninsula within the Port Jefferson Harbor complex and is west of Port Jefferson Harbor, northwest of Setauket Harbor, and east of Conscience Bay.

Much of the shoreline is unsewered and served by cesspools or septic tanks. Port Jefferson village at the southern end of Port Jefferson Harbor is served by the Port Jefferson sewage treatment plant. The State University of New York at Stony Brook is served by the Stony Brook sewage treatment plant and shares an outfall with the Port Jefferson sewage treatment plant at the southern end of Port Jefferson Harbor. For regulatory (shellfish) purposes, the NYSDEC distinguishes between Port Jefferson Harbor North, Port Jefferson Harbor South, and Conscience Bay (fig. 1).

Land use in the surrounding area is primarily low- to medium-density residential, with commercial and industrial uses on the southern ends of Port Jefferson Harbor and Setauket Harbor. There are low-density residential areas on the eastern side of Port Jefferson Harbor and on the western and southern sides of Conscience Bay. Conscience Bay is connected to the northern side of Port Jefferson Harbor by the Narrows, which is a narrow channel to the north of Strongs Neck. Conscience Bay differs from Port Jefferson Harbor in that it is shallow and surrounded primarily by low-density residential land use. Port Jefferson Harbor has deep navigation channels to support industrial and commercial facilities, including a ferry service operating between Port Jefferson Harbor and Bridgeport, Connecticut. Potential contributions of contaminated water to the harbor include storm runoff,



Figure 1. Map showing the extent of the priority waterbodies in the Port Jefferson Harbor complex on Long Island, New York, as designated by the New York State Department of Environmental Conservation (2020); the sewerage area surrounding the Port Jefferson Harbor complex and the Port Jefferson Sewage Treatment Plant are indicated. Areas that are not sewerage are served by cesspools or septic tanks.

4 Microbial Source Tracking To Identify Contamination Sources in Port Jefferson Harbor Complex on Long Island, New York

groundwater inputs, and drainage of coastal ponds, creeks, and wetlands. Illicit boat discharges and effluent from the Port Jefferson and Stony Brook University sewage treatment plants are also possible contributors of fecal contamination to the harbor. Industrial activities on the western side of Port Jefferson Harbor directly discharge water used for cooling. Moderately to steeply sloping bluffs along the eastern edge of Port Jefferson Harbor are typical of the northern shore of Long Island and allow for rapid delivery of stormwater through direct runoff or storm drains. The sites where surface-water samples were collected (U.S. Geological Survey, 2020a) for the Port Jefferson Harbor complex (fig. 2; tables 1.1 and 2.1) are as follows:

- The Culvert North of State Route 25A sampling site flows under State Route 25A into the southern end of Setauket Harbor at East Setauket Pond Park. The pond is home to waterfowl. The culvert directs water from

ponds and wetlands along the eastern side of Gnarled Hollow Road into Setauket Harbor and flows in dry weather conditions.

- The Culvert North of Shore Road sampling site drains wetlands, ponds, and stormwater runoff directly into Scotts Cove on the southeastern side of Setauket Harbor and flows continuously, even in dry weather conditions.
- The Old Mill Creek Culvert sampling site continuously drains water from Old Mill Creek, a groundwater-fed stream, with stormwater inputs in wet weather, into southern Port Jefferson Harbor.
- The Outfall Near Danfords Marina sampling site directs stormwater runoff from adjacent parking areas and marina. This outfall is only visible at low tide.

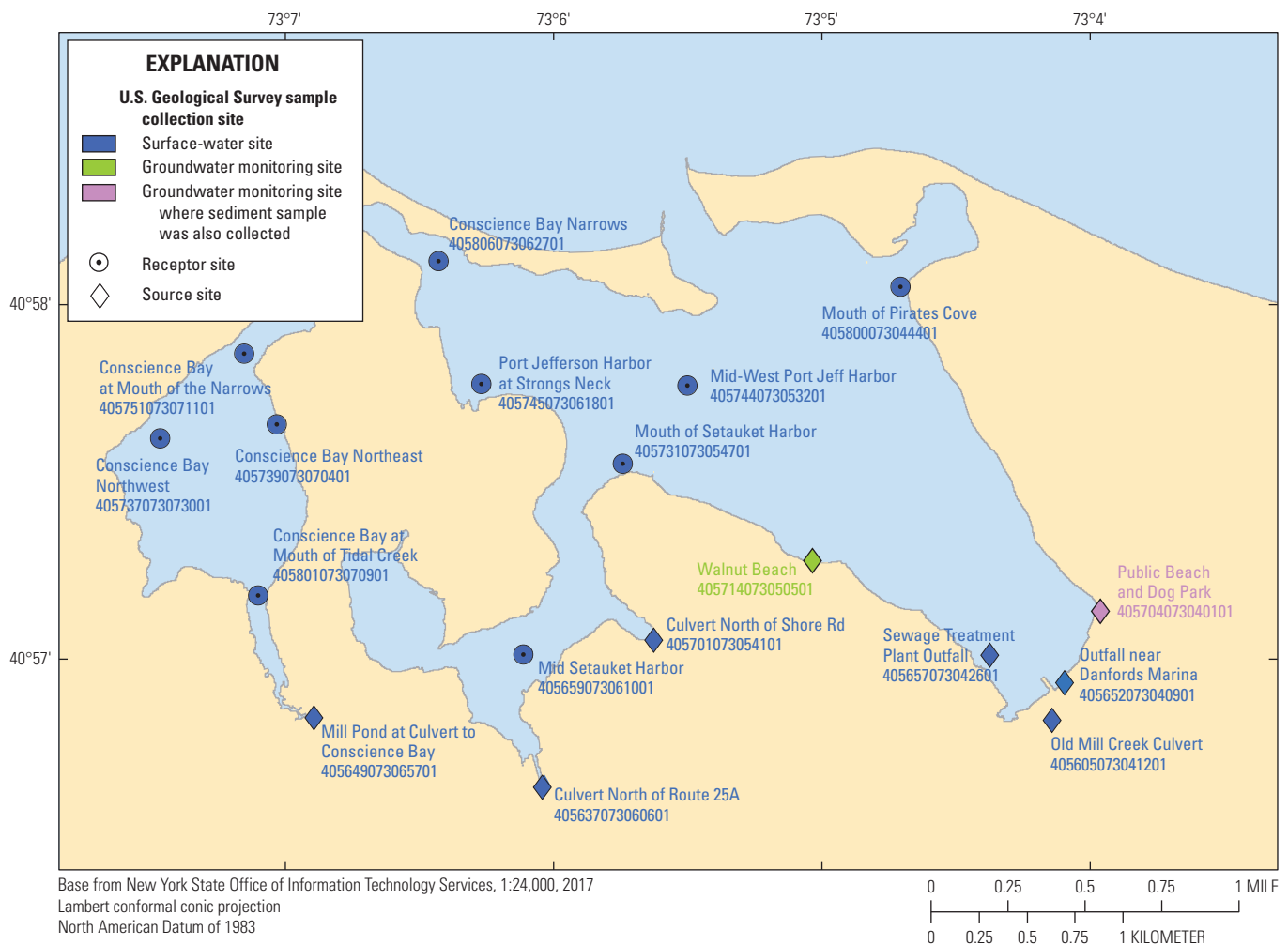


Figure 2. Map showing locations where surface-water (blue), and groundwater (green) plus sediment (purple) samples were collected by the U.S. Geological Survey for microbial source tracking in the Port Jefferson Harbor complex on Long Island, New York. Data are from U.S. Geological Survey (2020a).

- The Sewage Treatment Plant Outfall sampling site is at the southern end of Port Jefferson Harbor and discharges water treated through an ultraviolet disinfection system from the Port Jefferson and Stony Brook sewage treatment plants.
- The Mill Pond Culvert to Conscience Bay sampling site directs water from Setauket-Mill Pond, including its inland pond tributaries, into Conscience Bay.

Approach and Methods

Sampling.—Samples were collected and analyzed in accordance with methods detailed in Tagliaferri and others (2021). Groundwater and sediment samples in Port Jefferson Harbor were collected in November 2018. No groundwater or sediment samples were collected in Conscience Bay during this sample collection.

On the basis of the methodology used for this study, wet conditions were defined as more than 0.25 inch of precipitation in 24 hours or 0.50 inch in 48 hours, and dry conditions were defined as less than 0.25 inch of precipitation in 72 hours. Rainfall totaled 1.21 inches on July 17, 2018, and 0.11 inch on July 18, 2018, designating samples collected in Port Jefferson Harbor and Setauket Harbor on July 18, 2018, as summer wet samples (more than 0.25 inch within 24 hours). Winter wet samples were also collected in Port Jefferson Harbor and Setauket Harbor on April 1, 2019, with 0.26 inch of precipitation falling on March 31, 2019. Rainfall totaled 3.57 inches on September 25, 2018, and 0.39 inch September 26, 2018, designating samples collected in Conscience Bay on September 26, 2018, as summer wet samples. Samples were collected in Conscience Bay on April 9, 2019, with 0.13 inch of precipitation falling on April 8, 2019, and 0.04 inch falling on April 9, 2019, totaling 0.17 inch of rain in 24 hours. Although these measurements fall outside the wet sample criterion of 0.25 inch in 24 hours, samples collected on April 9, 2019, were considered to be winter wet samples. Rainfall values were obtained from the Stony Brook mesonet weather gages identified as “South P Lot” and “Health Science Center” weather stations (Stony Brook University Weather, 2021).

From June 2018 to April 2019, 13 sites were sampled within Port Jefferson Harbor and Setauket Harbor, yielding 43 surface-water samples (including 1 replicate and 1 blank sample), 2 groundwater samples, and 1 sediment sample collected concurrently with the groundwater sample at the Public Beach and Dog Park (fig. 2). Of the surface-water sites, five were considered source sites (waters flowing directly into the Port Jefferson Harbor complex from the land through culverts and groundwater discharge), and six were considered receptor sites (the harbor itself). Twenty surface-water samples were

collected under wet conditions, and 18, under dry conditions; 20 surface-water samples were collected in the summer, and 18, in the winter.

From September 2018 to May 2019, 5 sites were sampled within Conscience Bay, yielding 25 surface-water samples (including 3 replicates and 2 blank samples). No groundwater or sediment sample was collected around Conscience Bay. One of the sample sites was considered a source site, and four were considered receptor sites. Ten samples were collected under wet conditions, and 10, under dry conditions; 10 samples were collected in the summer, and 10, in the winter.

Laboratory analysis.—Laboratory methods used for this study are detailed in Fisher and others (2020). Samples for FC were analyzed at the Suffolk County Department of Health Services Public Environmental Health Laboratory (PEHL) and the NYSDEC Marine Laboratory. Additional information was either observed or compiled to facilitate interpretation of data. Precipitation measurements were collected from the Stony Brook University weather stations designated as South P Lot and Health Science Center that are approximately 4.5 and 3.5 miles from the center of Conscience Bay, respectively (Stony Brook University Weather, 2021). Quality assurance for samples collected at the Stony Brook University weather stations are not available.

Approximate tide stage based on tidal predictions available (National Oceanic and Atmospheric Administration, undated) was documented along with the sample information in the National Water Information System (NWIS; U.S. Geological Survey, 2020a). Land-cover and sewer district geographic information system coverages (Nassau County, 2015; Suffolk County, 2020; U.S. Geological Survey, 2020b) were used for data interpretation. These data support the MST results to increase confidence in the geographical source of the water and likely transport mechanisms of fecal contamination to Port Jefferson Harbor, Setauket Harbor, and Conscience Bay.

Results

Results of MST and FC were assessed based on concentrations, presence or absence, and relative abundance of host markers with respect to surface-water source and receptor sites. Differences in MST markers and FC concentrations were also compared seasonally and conditionally (that is, wet or dry), with dry weather discharges with high FC concentrations from municipal separate storm sewer system source sites being of particular concern.

Microbial Source Tracking

Throughout Port Jefferson Harbor and Setauket Harbor, human-associated *Bacteroides* (HF183) markers were detected in more than half of the surface-water samples from source and receptor sites. Ruminant-associated *Bacteroides*

(Rum2Bac) marker was detected in only one source sample collected in the summer in wet weather. There were eight detections for the waterfowl-associated *Helicobacter* (GFD) marker that were evenly split between summer and winter seasons and wet and dry conditions; however, seven detections were at source sites, and only one, at a receptor site, suggesting concentrated avian fecal contamination in inland ponds and creeks. For HF183, samples collected during wet weather and dry weather had similar detections above the reporting limit (70 and 61 percent, respectively; [table 1](#)). This may indicate a constant source of fecal contamination entering Port Jefferson Harbor and Setauket Harbor that is unrelated to weather events. The canine-associated *Bacteroides* (BacCan) marker was detected in 28 percent of winter samples, and 35 percent of summer samples ([table 1](#)), which may reflect the year-round use of public space for dog walking. During wet and dry weather, BacCan was detected in 30 and 33 percent of samples, respectively, similar to the HF183 marker detections, suggesting canine influence is unrelated to weather events.

Throughout Conscience Bay, HF183 markers were not detected in 4 samples at the single source site but were detected in 5 out of 16 samples from receptor sites ([table 1](#)). BacCan markers were detected in 50 percent of source site samples and 31 percent of receptor site samples. Rum2Bac markers were not detected in any samples, suggesting little

Table 1. Summary of microbial source tracking results in surface-water samples for sites sampled in Port Jefferson Harbor, Setauket Harbor, and Conscience Bay on Long Island, New York.

[Ratios are number of samples with detections greater than reporting limit per total number of samples. Reporting limits vary due to analytical processes and matrix interferences. HF183, human *Bacteroides* marker; Rum2Bac, ruminant *Bacteroides* marker; GFD, waterfowl *Helicobacter* marker; BacCan, canine-associated *Bacteroides* marker]

Variable	Ratio of positive detections (detection greater than reporting limit)			
	HF183	Rum2Bac	GFD	BacCan
Port Jefferson Harbor and Setauket Harbor				
Summer	12:20	1:20	4:20	7:20
Winter	13:18	0:18	4:18	5:18
Dry	11:18	0:18	4:18	6:18
Wet	14:20	1:20	4:20	6:20
Source	13:17	1:17	7:17	11:17
Receptor	12:21	0:21	1:21	1:21
Conscience Bay				
Summer	3:10	0:10	4:10	6:10
Winter	2:10	0:10	4:10	1:10
Dry	2:10	0:10	3:10	2:10
Wet	3:10	0:10	5:10	5:10
Source	0:4	0:4	1:4	2:4
Receptor	5:16	0:16	7:16	5:16

or no contribution from the resident deer population. There were eight detections for the GFD marker that were evenly split between summer and winter seasons, with three occurring during dry weather, and five occurring during wet weather. In contrast to Port Jefferson Harbor and Setauket Harbor, one of these detections occurred at the source site, and seven, at receptor sites, suggesting concentrated avian fecal contamination originating within Conscience Bay and not from surrounding sources. For HF183, samples collected during wet and dry weather had similar detections above the reporting limit (30 and 20 percent, respectively; [table 1](#)). This may indicate a constant source of fecal contamination entering Conscience Bay that is unrelated to weather events. For BacCan, one positive sample was detected in winter, and six positive samples were observed in summer ([table 1](#)), which may reflect a seasonal influence from the surrounding residential communities. BacCan detections during wet and dry weather were 50 and 20 percent, respectively, suggesting canine influence may also be related to weather events in this area.

Host Specific Markers

Reporting limits for the three MST markers (human, canine, and waterfowl) predominantly detected in Port Jefferson Harbor, Setauket Harbor, and Conscience Bay varied slightly because of analytical processes, such as required dilutions because of matrix interferences. Understanding occurrence of the predominant MST markers in the Port Jefferson Harbor complex can help prioritize locations for additional investigation and infrastructure improvement and provide a baseline for host contributions when prioritizing sites of concern for assessing FC and after total maximum daily load implementation.

HF183

In Port Jefferson Harbor and Setauket Harbor, the human marker was detected at least once in surface-water samples at each receptor site (with the exception of Mid Setauket Harbor where only one sample was collected during the study), which is indicative of continuous inputs from potential inland sources (including illicit connections to the stormwater drain system and the Port Jefferson sewage treatment plant) or sources from within the receptor (including boats and marinas). Concentrations of the human marker were of the same order of magnitude (hundreds of copies per 100 milliliters [mL]; [table 1.2](#)) at receptor sites ([fig. 3](#)). These detections within the harbor were close to the reporting limit and not associated with high FC concentrations, thereby making it unlikely that the source was from boats and marinas. The Culvert North of State Route 25A and sewage treatment plant outfall sites were the only source sites where the human marker was detected in all four samples; however, all sewage treatment plant outfall samples and winter samples at Culvert North of State Route 25A were associated with low to nondetectable FC

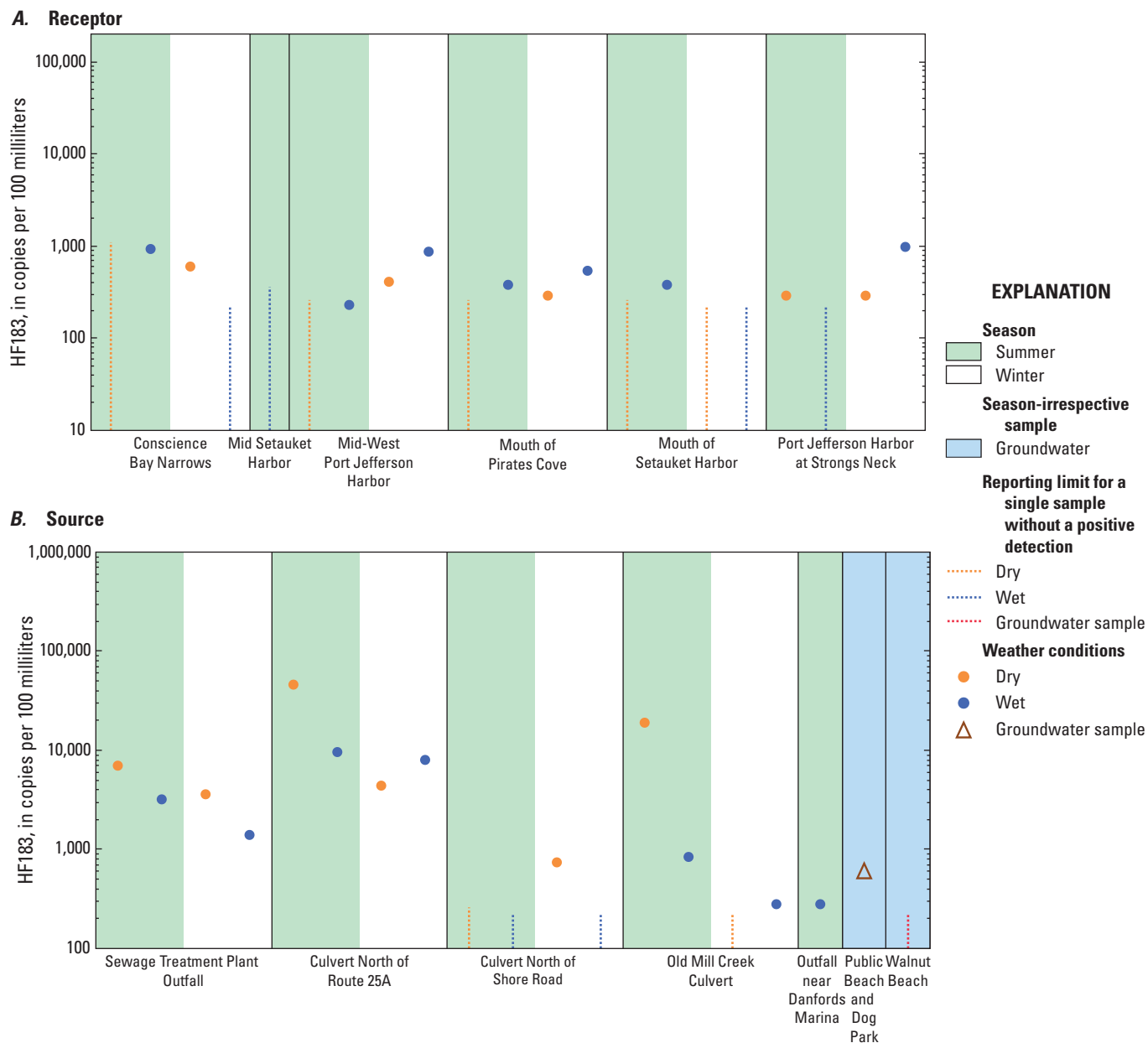


Figure 3. Graphs showing concentrations of the human *Bacteroides* (HF183) marker, in copies per 100 milliliters, from **A**, receptor and **B**, source sites under various surface-water sample conditions in Port Jefferson Harbor and Setauket Harbor on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

concentrations. Samples from 13 of 17 surface-water source sites in Port Jefferson Harbor and Setauket Harbor had detections of HF183 above the reporting limit. The concentration of HF183 in samples collected from the same site were on the same order of magnitude in dry and wet weather (between hundreds and thousands of copies per 100 mL; [table 1.2](#)), except summer, dry weather samples collected at the source sites Culvert North of State Route 25A (46,000 copies per 100 milliliters [copies/100 mL]) and Old Mill Creek Culvert (19,000 copies/100 mL). FC counts were generally higher in

all source sites during the summer as opposed to the winter, with median FC concentrations at 800 most probable number per 100 milliliters (MPN/100 mL) in the summer and 20 MPN/100 mL in the winter.

Conscience Bay had 5 positive HF183 detections of 20 total samples, all of which were at receptor sites. Two positive HF183 detections were in winter, dry weather samples, and the remaining three were in summer wet weather samples ([fig. 4](#)). Conscience Bay Northwest was the only receptor site within Conscience Bay with no positive HF183 detections.

The median HF183 concentration for all positive detections was 460 copies/100 mL. All samples collected during winter in wet weather and summer during dry weather had concentrations below the HF183 reporting limit. HF183 concentrations for the two detections in winter, dry weather samples were 360 and 1,200 copies/100 mL, and for the three summer, wet weather samples, 390, 470, and 460 copies/100 mL (table 2.2; U.S. Geological Survey, 2020a).

BacCan

At Port Jefferson Harbor and Setauket Harbor, the canine-associated *Bacteroides* (BacCan) marker was detected at 11 of 17 total source samples and 1 of 21 total receptor samples (table 1). Positive BacCan samples at the source sites were very similar between the winter and summer seasons, with one more positive detection in wet conditions than in dry (fig. 5). Conscience Bay Narrows is the only receptor site with a positive BacCan detection in Port Jefferson Harbor (2,000 copies/100 mL; table 1.2). Concentrations of BacCan were highest at the Culvert North of Shore Road (24,000 copies/100 mL) site in the winter, wet weather sample followed by the Culvert

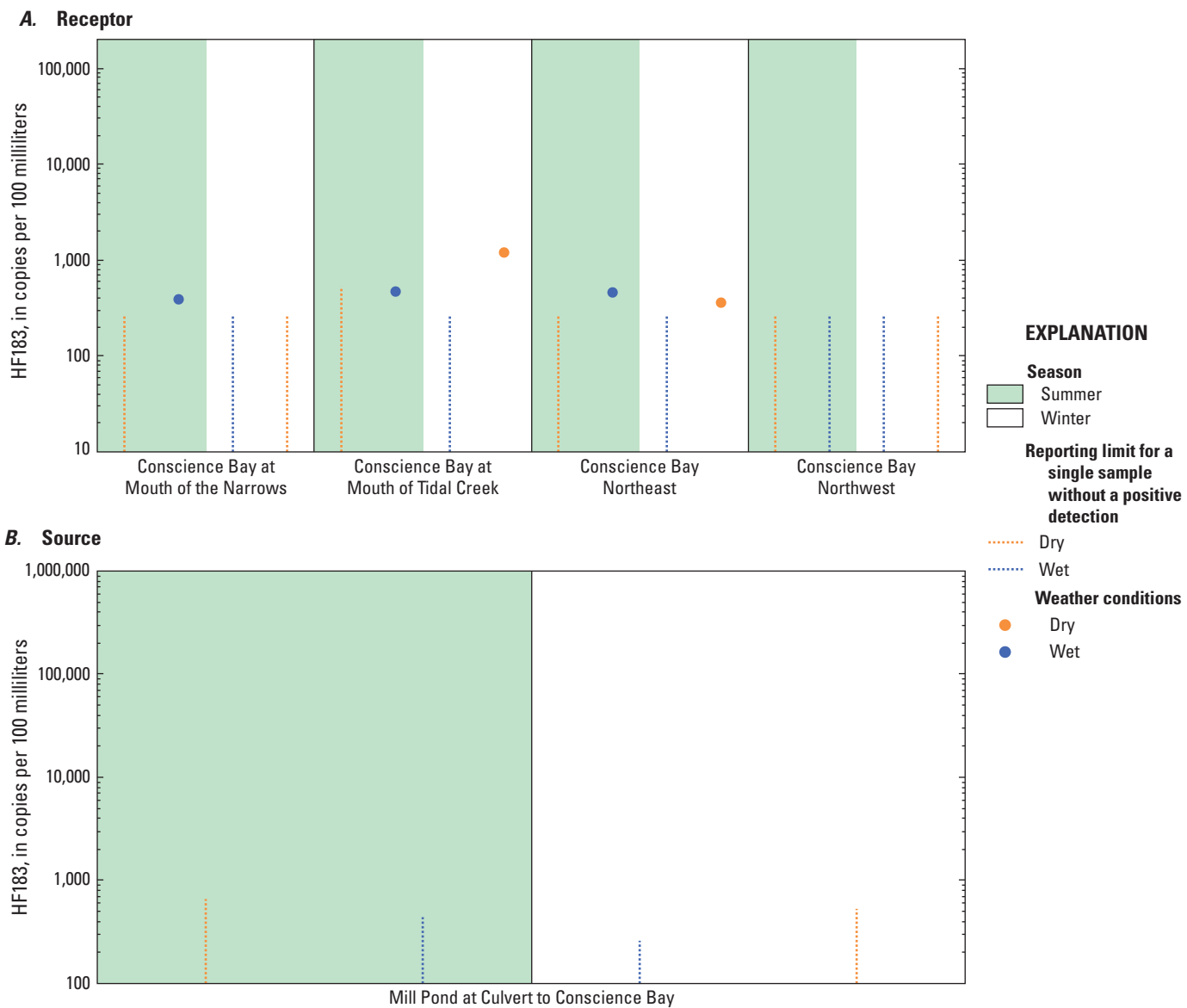


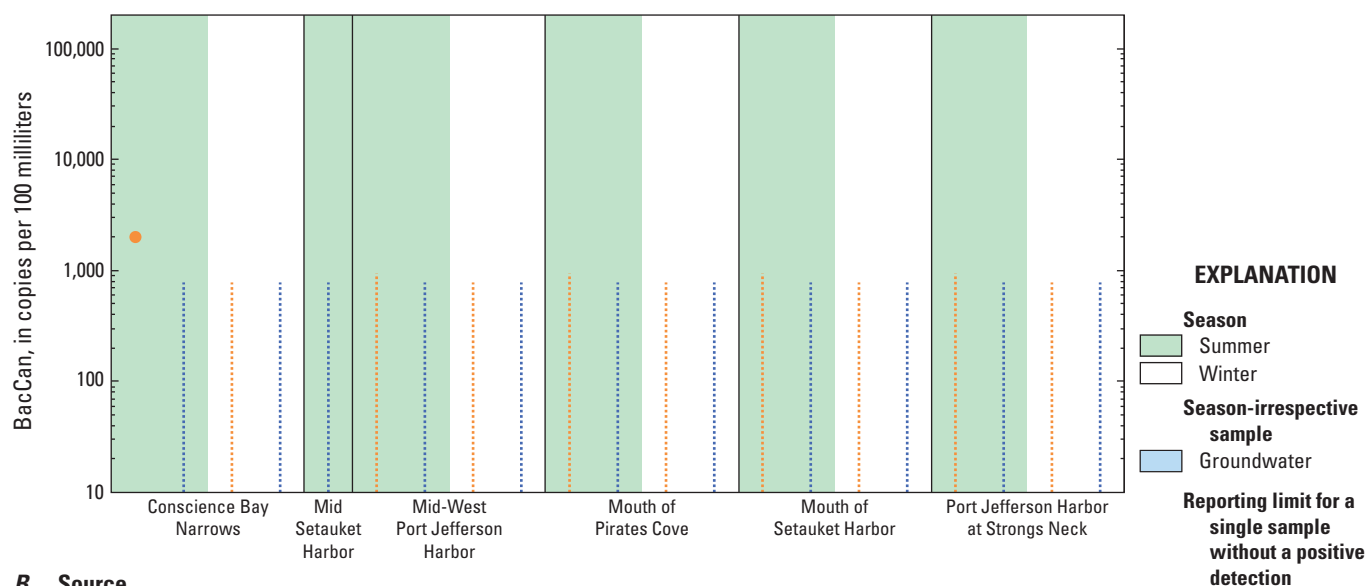
Figure 4. Graphs showing concentrations of the human *Bacteroides* (HF183) marker, in copies per 100 milliliters, from A, receptor and B, source sites under various surface-water sample conditions in Conscience Bay on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

North of State Route 25A (21,000 copies/100 mL) site in the summer, wet weather sample. All four samples taken at the Culvert North of State Route 25A and Culvert North of Shore Road sites yielded concentrations of BacCan above the reporting limit. BacCan was detected in the sediment sample (200 copies/100 mL; [table 1.2](#)) but not in the groundwater at the Public Beach and Dog Park site on the southeastern side of Port Jefferson Harbor.

Conscience Bay had seven positive BacCan detections, one detection at each of the five sampling sites plus one additional positive detection at the Conscience Bay at Mouth of

Tidal Creek and Mill Pond at Culvert to Conscience Bay sites. Five of seven positive detections (one at each site) were in the summer, wet weather samples ([fig. 6](#)). BacCan concentrations were highest at the Mill Pond at Culvert to Conscience Bay site, the single source site in Conscience Bay, during the summer, dry weather sample (28,000 copies/100 mL; [table 2.2](#)); this was the highest concentration detected in the Port Jefferson Harbor complex, with the exception of the summer wet weather replicate sample (110,000 copies/100 mL). In Conscience Bay, the only winter detection of BacCan was in dry weather at the Conscience Bay at Mouth of Tidal Creek

A. Receptor



B. Source

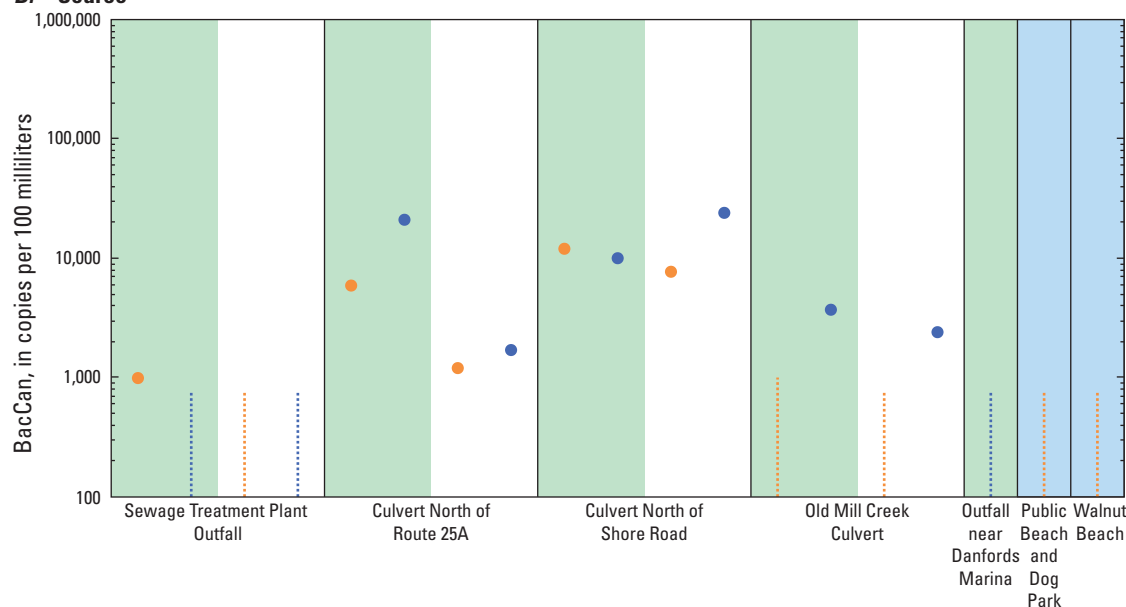


Figure 5. Graphs showing concentrations of the canine *Bacteroides* (BacCan) marker, in copies per 100 milliliters, from A, receptor and B, source sites under various surface-water sample conditions in Port Jefferson Harbor and Setauket Harbor on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

site and was the only winter sample associated with a high FC concentration. Every positive BacCan detection corresponded to a high FC concentration in Conscience Bay but not in Port Jefferson Harbor and Setauket Harbor.

GFD

The waterfowl-associated *Helicobacter* (GFD) marker was detected in 7 of 17 surface water samples taken at source sites and 1 of 21 samples for receptor sites at Port Jefferson Harbor and Setauket Harbor (table 1). All samples collected at the Culvert North of Shore Road site were positive for GFD, and the summer, dry weather sample at this site had the

highest concentration of GFD in the Port Jefferson Harbor complex (8,300 copies/100 mL; table 1.2). All GFD detections at surface-water source sites in Port Jefferson Harbor and Setauket Harbor were of the same order of magnitude (thousands of copies per 100 mL). Concentrations in Port Jefferson Harbor and Setauket Harbor were closer to the reporting limit (hundreds of copies per 100 mL) in the single receptor site with a positive detection (Mouth of Setauket Harbor) and in both the groundwater and sediment samples at the Public Beach and Dog Park site (fig. 7).

Conscience Bay had 8 positive GFD detections of 20 total samples. Seven of eight positive samples were at receptor sites, three at the Mouth of Tidal Creek site, three at the

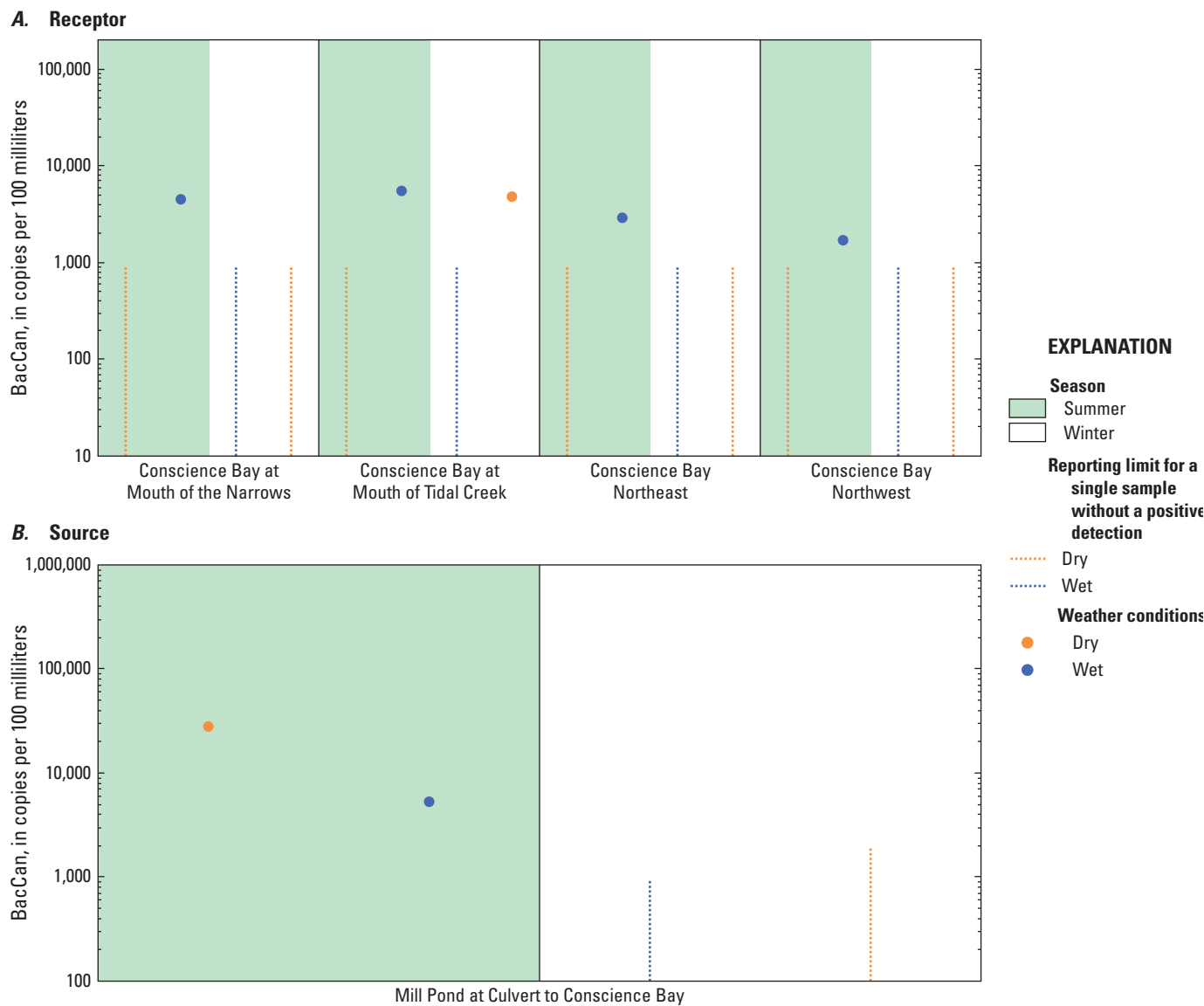


Figure 6. Graphs showing concentrations of the canine *Bacteroides* (BacCan) marker, in copies per 100 milliliters, from A, receptor and B, source sites under various surface-water sample conditions in Conscience Bay on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

Conscience Bay Northeast site, and one at the Mouth of the Narrows site (fig. 8). This is in contrast to Port Jefferson Harbor and Setauket Harbor where seven out of eight detections of GFD occurred in source samples. There were no positive GFD detections at the Conscience Bay Northwest site. The one positive GFD detection at a source site (Mill Pond at Culvert to Conscience Bay) was during the summer, dry weather sample. All detections were of the same order of magnitude (between hundreds and thousands of copies per 100 mL; table 2.2).

Fecal Coliform Bacteria

Port Jefferson Harbor and Setauket Harbor.— Concentrations of FC for samples from source sites collected in Port Jefferson Harbor, including Setauket Harbor, ranged from at or below the reporting limit in 44 percent of samples to 3,000 MPN/100 mL in two summer samples (table 1.2; U.S. Geological Survey, 2020a), one from the Culvert North of State Route 25A site and the other from Old Mill Creek Culvert site (both under wet weather conditions). Concentrations for samples collected at the receptor

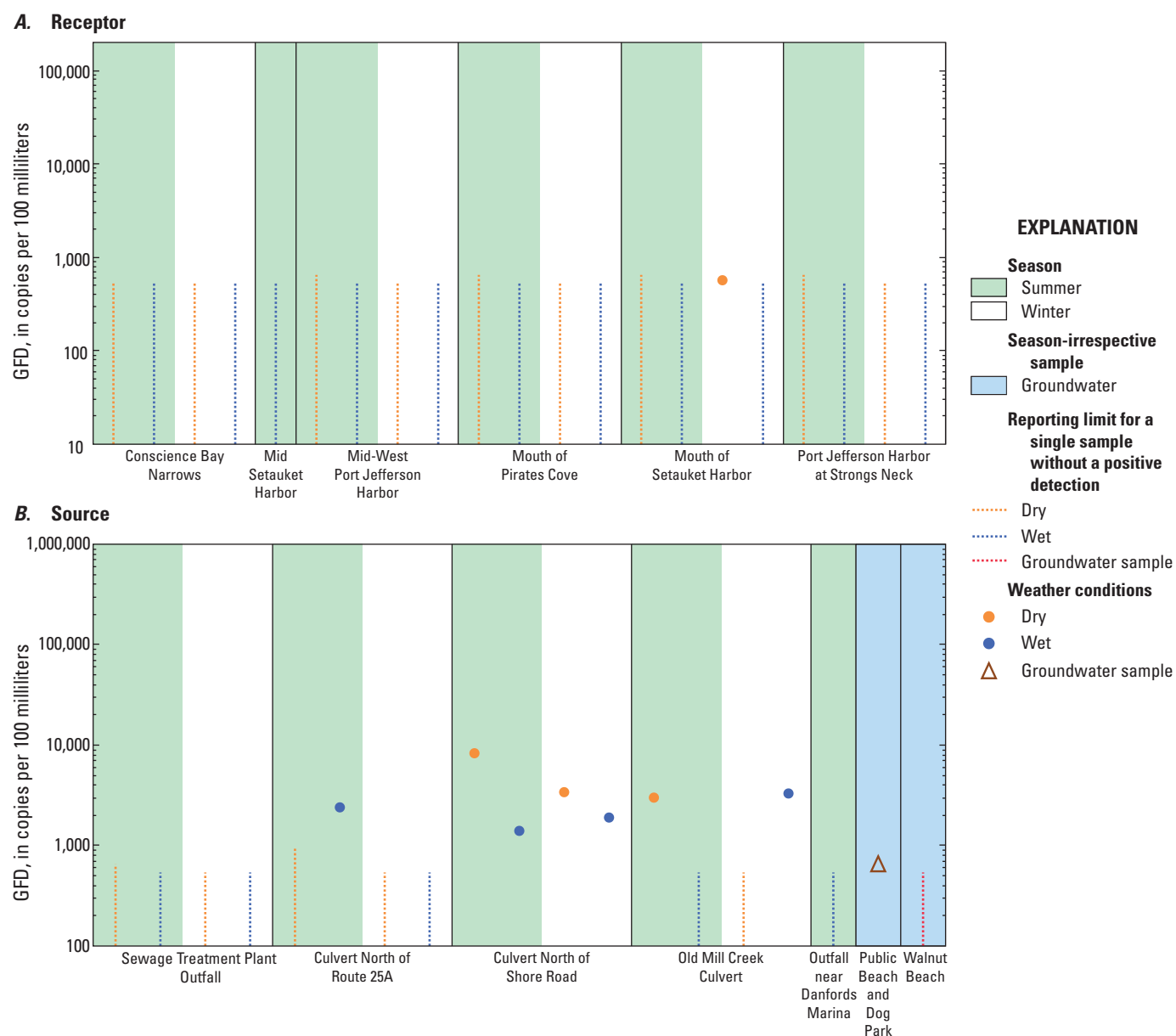


Figure 7. Graphs showing concentrations of the waterfowl *Helicobacter* (GFD) marker, in copies per 100 milliliters, from A, receptor and B, source sites under various surface-water sample conditions in Port Jefferson Harbor and Setauket Harbor on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

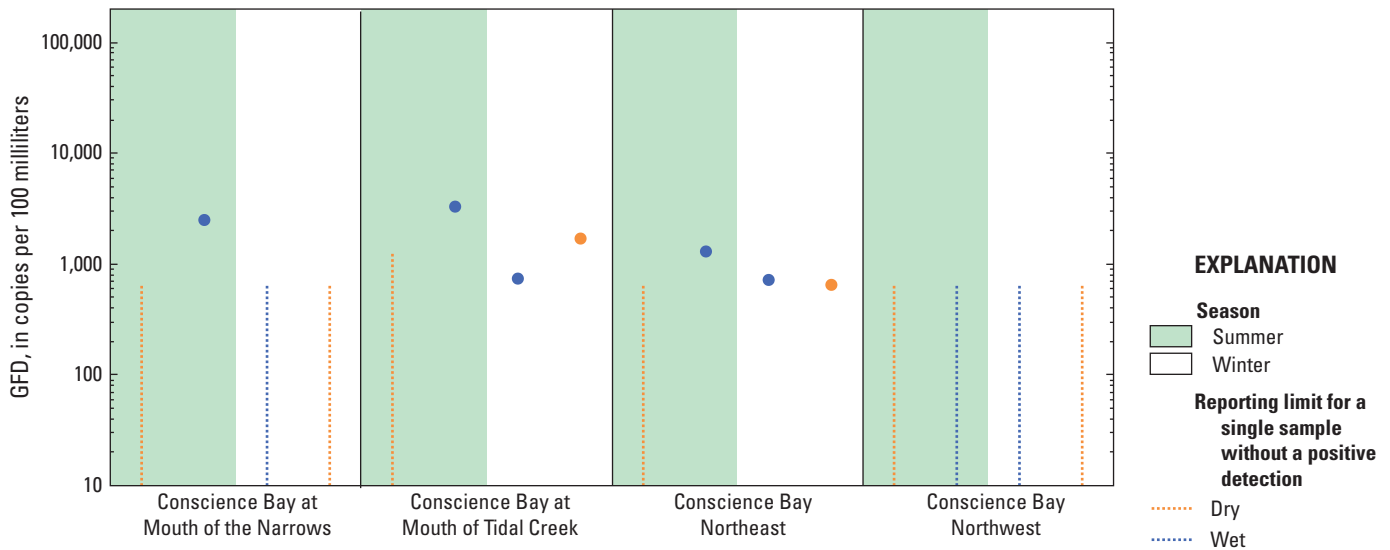
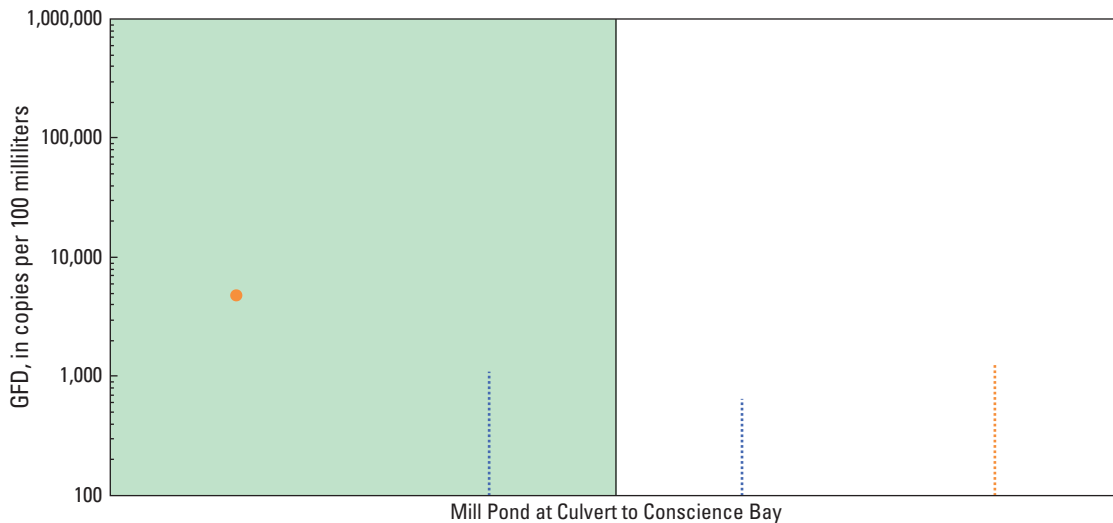
A. Receptor**B. Source**

Figure 8. Graphs showing concentrations of the waterfowl *Helicobacter* (GFD) marker, in copies per 100 milliliters, from *A*, receptor and *B*, source sites under surface-water sample conditions in Conscience Bay on Long Island, New York. Dashed lines indicate reporting limit for a single sample without a positive detection. Values for marker concentrations are fixed to allow for easy comparison with other embayment study areas on Long Island.

sites ranged from less than the reporting limit in 93 percent of samples to just at the reporting limit of 20 MPN/100 mL in one sample, in dry weather conditions at the Mouth of Pirates Cove site (table 1.2; U.S. Geological Survey, 2020a). During this study, none of the receptor samples collected in Port Jefferson Harbor and Setauket Harbor had concentrations above 49 MPN/100 mL, the 90th percentile concentration determined by the NYSDEC as part of the National Shellfish Sanitation Program (NSSP) closure criteria (U.S. Food and Drug Administration, 2019).

The two sites (Culvert North of State Route 25A and Sewage Treatment Plant Outfall) with the highest overall marker concentrations for HF183 and highest frequency of

detection for HF183 had differing FC concentrations, the highest for each being 3,000 MPN/100 mL at the Culvert North of State Route 25A site and near the reporting limit of 20 MPN/100 mL at the Sewage Treatment Plant Outfall site (for comparable PEHL data) or 43 MPN/100 mL (for NYSDEC data), both of which are below the 49 MPN/100 mL closure criteria. In samples collected at the Culvert North of Shore Road site, the BacCan and GFD markers were detected in all samples, corresponding to FC concentrations of 300 MPN/100 mL in summer dry conditions, 800 MPN/100 mL in summer wet conditions, 20 MPN/100 mL in winter dry conditions, and 330 MPN/100 mL in winter wet conditions. At the Outfall near Danfords Marina site,

FC was detected at a concentration of 1,300 MPN/100 mL corresponding to a human marker detection in wet, summer conditions in the single sample collected at this site (table 2.2; U.S. Geological Survey, 2020a).

Conscience Bay.—Concentrations of FC for samples collected in Conscience Bay from the single source site (Mill Pond at Culvert to Conscience Bay) ranged from near the reporting limit in the two winter samples (20 and 45 MPN/100 mL) to 5,000 MPN/100 mL in the two summer samples, one occurring under wet and one under dry conditions. Concentrations for samples collected at the receptor sites ranged from less than the reporting limit in 38 percent of samples to 2,400 MPN/100 mL in two samples, both occurring in the summer, one under wet and one under dry conditions, at the same site (Conscience Bay at Mouth of Tidal Creek). Of the receptor samples, 56 percent had concentrations above 49 MPN/100 mL. FC concentrations at the receptor sites ranged from 500 to 2,400 MPN/100 mL in the four samples that had three marker detections (HF183, GFD, and BacCan) at the Conscience Bay at Mouth of Tidal Creek (two samples), Conscience Bay at Mouth of the Narrows, and Conscience Bay Northeast sites. In the two samples where GFD was the only marker detected at the Conscience Bay at Mouth of Tidal Creek and Conscience Bay Northeast sites, FC concentrations were below or just above the reporting limit of 18 MPN/100 mL (table 2.2; U.S. Geological Survey, 2020a).

The relation between FC concentration and marker detection is not straightforward. FC and specific host-associated markers may decay at different rates and be present in different abundances. Host-associated markers were shown to decay more rapidly than FC in Rogers and others (2011) and Drozd and others (2013). In general, high FC concentrations were found during the summer season in both wet and dry weather.

Nonpoint Sources of Fecal Coliform Bacteria

Major nonpoint contributors of freshwater to the Port Jefferson Harbor complex include groundwater seepage and direct stormwater runoff not conveyed by the municipal separate storm sewer system. Groundwater was collected from two sites (Public Beach and Dog Park and Walnut Beach). Fecal indicator bacteria were not detected in either groundwater sample (table 2.1). At the Public Beach and Dog Park site, which is downgradient from an unsewered residential area on the bluffs above the beach, HF183 and GFD were detected in shallow groundwater (within 10 feet below land surface) at concentrations of 600 and 650 copies/100 mL, respectively.

Another nonpoint source that can contribute to fecal contamination in water samples is sediment during resuspension (O'Mullan and others, 2019). To better understand these contributions, a sediment sample was collected at the Public Beach and Dog Park site. This sample was positive for human, waterfowl, and canine MST markers, with concentrations of 100 copies/100 mL for HF183, 680 copies/100 mL for GFD,

and 200 copies/100 mL for BacCan, respectively (table 1.2; U.S. Geological Survey, 2020a). Fecal coliform was not measured.

Classification of Source Sites

The sites in the Port Jefferson Harbor complex were assessed to better understand geographical sources and transport mechanisms to surface-water receptor sites and the relationship between FC and MST marker presence and abundance (table 2). Source sites were assigned a numeric classification as described in Tagliaferri and others (2021) to aid managers with potential remediation efforts (table 3). Class 1 sites have the highest levels of contamination and class 5 sites have the least. Sites designated as sources to the Port Jefferson Harbor complex are further characterized below.

Culvert North of State Route 25A—Class 1

The samples collected at the Culvert North of State Route 25A site had some of the highest concentrations of both human and canine markers in the Port Jefferson Harbor complex and elevated concentrations of FC in summer samples in wet and dry weather (3,000 and 800 MPN/100 mL, respectively). Human and canine markers were detected in all samples, and waterfowl markers were also detected in the summer, wet weather sample. This is likely due to congregation of waterfowl in summer months at the East Setauket Pond Park. Winter samples had lower human and canine marker concentrations than in the summer, and low FC concentrations were observed in both wet and dry weather. Stormwater influence on FC concentrations has an effect at this site, as indicated by the observed increase in FC concentration during wet weather events relative to dry weather in both the summer and winter seasons. The culvert flows continuously and is suspected to contribute high FC concentrations related to stormwater catch basins and inland wetlands and ponds, particularly during the summer season.

Culvert North of Shore Road—Class 1

The culvert north of Shore Road collects stormwater and directs discharge from inland ponds and wetlands into Scotts Cove in Setauket Harbor. The culvert contributed high FC concentrations to Scotts Cove in all samples except the dry weather winter sample. Canine and waterfowl markers were present in all four samples collected, with ruminant (deer) and human markers each present in one sample. The human marker was detected only in the winter dry sample that was associated with a low FC concentration (20 MPN/100 mL). The ruminant marker was only detected in the summer wet sample that was associated with the highest FC concentration (800 MPN/100 mL). Samples at this location

Table 2. Geographical sources of water for sample locations and the potential for these sites to have contributed to the fecal coliform concentrations observed in the samples.

[X, potential contributor, —, not a likely contributor based on current data; FC, fecal coliform bacteria]

Site name	Embayment	Geographical source	Contributes to fecal contamination in harbor?	Remarks
Culvert North of State Route 25A	Setauket Harbor	Pond and wetland drainage	X	Pond and wetland drainage is a substantial source of fecal coliform bacteria (FC) in summer months contributing both human and canine waste.
		Stormwater conveyance	X	Stormwater contribution from adjacent roadways and into draining ponds and wetlands in wet weather flushes FC into Setauket Harbor, particularly in the summer season. Culvert contributes human, canine, and waterfowl waste.
Culvert North of Shore Road	Setauket Harbor	Pond and wetland drainage	X	Pond and wetland drainage is a substantial source of FC in summer months contributing both canine and waterfowl waste.
		Stormwater conveyance	X	Stormwater collected from adjacent roadways is a substantial source of FC year-round.
Old Mill Creek Culvert	Port Jefferson Harbor	Groundwater	—	Groundwater contribution of FC is not substantial, however, failing onsite wastewater disposal systems could result in overland flows into the creek or direct seepage of contaminated groundwater.
		Stormwater conveyance	X	Stormwater contributions from impervious surfaces in Port Jefferson Village are a substantial source of FC in the summer months. Culvert contributes human, canine, and waterfowl waste.
Outfall Near Danfords Marina	Port Jefferson Harbor	Stormwater conveyance	X	Stormwater is a substantial source of FC as shown in the single summer sample collected at this site. Presence of human markers indicates that there are potential illicit sewer hookups to storm drain system.
Sewage Treatment Plant Outfall	Port Jefferson Harbor	Sewage treatment plant	—	Disinfection processes and high concentrations of human markers coupled with low to absent FC suggest that FC inputs to Port Jefferson Harbor from this source are not likely.
Public Beach and Dog Park	Port Jefferson Harbor	Groundwater	—	Groundwater contribution of FC is not substantial though the presence of human markers indicates influence from onsite cesspools and septic systems.
		Sediment resuspension	—	Sediment in this area indicated evidence of fecal contamination from humans, canines, and waterfowl, however, FC is likely low due to the sandy nature of the soil.
Walnut Beach	Port Jefferson Harbor	Groundwater	—	Groundwater contribution of FC is not likely. No microbial source tracking markers were detected.
Mill Pond Culvert to Conscience Bay	Conscience Bay	Pond drainage	X	Pond drainage is a substantial source of FC in the summer months and associated with canine waste.

Table 3. Sample results for fecal coliform and microbial source tracking markers by source site type at Port Jefferson Harbor, Setauket Harbor, and Conscience Bay on Long Island, New York.

[Proposed classification considers concentrations of fecal coliform bacteria (FC) above 49 most probable number per 100 milliliters (MPN/100 mL), dry weather discharges, and influences of human sewage and canine waste. A fecal coliform concentration of 49 MPN/100 mL is the 90th percentile concentration determined by the New York State Department of Environmental Conservation as part of the National Shellfish Sanitation Program closure criteria (U.S. Food and Drug Administration, 2019). HF183, human *Bacteroides* marker; BacCan, canine-associated *Bacteroides* marker; —, no data]

Site name	Site type	Number of FC samples	Fecal coliform (MPN/100 mL)				Elevated fecal coliform during dry weather discharge	Sewage affected (HF183)	Canine affected (BacCan)	Class ¹
			Median	25th quartile	75th quartile	Mean				
Culvert North of State Route 25A	Pond drainage	4	423	39	1,350	966	Yes	Yes	Yes	1
Culvert North of Shore Road	Pond drainage	4	315	230	448	363	Yes	Yes	Yes	1
Old Mill Creek Culvert	Tidal stream	4	410	15	1,350	955	Yes	Yes	Yes	1
Outfall Near Danfords Marina	Outfall	1	—	—	—	—	—	Yes	No	3
Sewage Treatment Plant Outfall	Outfall	4	20	10	20	13	No	Yes	Yes	5
Public Beach and Dog Park	Groundwater	1	—	—	—	—	—	Yes	No	5
Public Beach and Dog Park	Sediment	1	—	—	—	—	—	Yes	Yes	5
Walnut Beach	Groundwater	1	—	—	—	—	—	No	No	5
Mill Pond Culvert to Conscience Bay	Pond drainage	4	2,520	39	5,000	2,520	Yes	Yes	Yes	1

¹Class is assigned from 1 to 5, with 1 being the most contaminated and 5 being the least contaminated.

had higher FC concentrations during wet weather (800 and 330 MPN/100 mL) compared with dry weather (300 and 20 MPN/100 mL). This location is primarily affected by upland surface-water and stormwater drainage that contributes substantial FC to Scotts Cove in both wet and dry weather.

Mill Pond Culvert to Conscience Bay—Class 1

The Mill Pond culvert to Conscience Bay drains water from Setauket Mill Pond and inland tributaries to Conscience Bay. Setauket Mill Pond is within the Frank Melville Memorial Park and is surrounded by wooded areas, historic buildings, and low-density residential housing. FC concentrations were high (5,000 MPN/100 mL) in both summer samples, in wet and dry weather conditions. Canine markers were detected in both summer samples, with the highest canine marker concentration (28,000 copies/100 mL) found in the Port Jefferson Harbor complex occurring in the dry weather sample. These canine marker concentrations were similar to the winter, wet weather sample at the Culvert North of Shore Road site (24,000 copies/100 mL). In comparison, the summer, wet weather sample had a canine marker concentration of 5,300 copies/100 mL. No markers were detected in the winter season, and the associated FC concentration was low (20 MPN/100 mL in wet weather and 45 MPN/100 mL in dry weather). As FC concentrations are high in both wet and dry weather in the summer, it is suspected that dog waste entering upland tributaries from residential communities and heavier use of the park in warmer months may be the primary sources of fecal contamination flowing through the Mill Pond culvert to Conscience Bay.

Old Mill Creek Culvert—Class 1

Old Mill Creek flows through Port Jefferson village and continues through the culvert into the southern end of Port Jefferson Harbor. This study found the creek to be a consistent source of FC in the summer season in both wet and dry conditions. Human, canine, and waterfowl markers were all detected; however, no markers were present in the winter, dry weather sample. The highest human marker concentration did not correspond to the highest FC concentrations. The human marker was detected in three of the four samples, with the highest concentration measured in the summer, dry weather sample (1,900 copies/100 mL) and the associated FC concentration at 800 MPN/100 mL. The highest FC concentration was measured in the summer, wet weather sample (3,000 MPN/100 mL) and corresponded to a human marker concentration of 840 copies/100 mL. The canine marker was only detected during wet weather, though the winter, wet weather sample had a very low FC concentration (20 MPN/100 mL). Populations of humans, canines, and birds are greatest in the summer season and may contribute to the seasonal observation of FC. Lower FC in the summer dry

sample and lack of markers and FC in the winter dry sample indicate stormwater over groundwater as a substantial contributor to FC.

Outfall Near Danfords Marina—Class 3

The outfall near Danfords Marina directs stormwater from impervious surfaces in Port Jefferson village to Port Jefferson Harbor. Because it is only accessible at low tide, the site was only sampled once during the summer after wet weather. Only human markers were detected at a concentration of 280 copies/100 mL, and FC concentration was high (1,300 MPN/100 mL). Although only one sample was collected, it appears that this location may contribute substantial FC from stormwater. The presence of human markers may indicate the presence of potentially illicit sewer hookups to the storm drain system.

Sewage Treatment Plant Outfall—Class 5

The sewage treatment plant outfall discharges treated sewage from both the Port Jefferson and Stony Brook sewage treatment plants into the southern end of Port Jefferson Harbor. Water entering both sewage treatment plants undergo tertiary treatment and disinfection by ultraviolet light. FC concentrations were low and ranged from nondetect (less than 18 MPN/100 mL) to 20 MPN/100 mL in samples analyzed by the PEHL or to 43 MPN/100 mL in samples analyzed by the NYSDEC. Human markers were detected in all four samples on the order of thousands of copies per 100 mL, consistently higher than other source sites. These results show that the sewage treatment plant outfall is not a significant source of FC to Port Jefferson Harbor but may contribute to the presence of human markers detected in receptor samples.

Sediment—Class 5

Recent research (Hassard and others, 2016; O'Mullan and others, 2019) shows that resuspension of sediment, particularly organic sediment, along natural shorelines can cause a spike in FC concentrations. Therefore, it is likely that, during conditions that result in high wave energy, sediment can act as a source of FC when resuspended in the water column as a result of tidal movement, storms, or boat activity. FC was not analyzed in the sandy sediment sample collected at the Public Beach and Dog Park site on the eastern side of Port Jefferson Harbor; however, human, waterfowl, and canine markers were found, indicating evidence of fecal contamination. Sandy sediment in this area is likely not a significant source of FC to Port Jefferson Harbor.

Groundwater—Class 5

The lack of positive detections of FC in groundwater suggests that direct groundwater seepage is an unlikely contributor of FC to the Port Jefferson Harbor complex. The positive human markers at the Public Beach and Dog Park site (in both groundwater and sediment) imply septic influence but not a source of FC.

Summary

The U.S. Geological Survey worked collaboratively with the New York State Department of Environmental Conservation to assess the potential sources of fecal contamination entering seven estuarine embayments across Long Island, New York, from June 2018 to July 2019. Water samples are routinely collected by the New York State Department of Environmental Conservation in Long Island embayments and analyzed for fecal coliform bacteria, an indicator of fecal contamination, to determine the closure of shellfish beds for harvest and consumption. Concentrations of fecal coliform signify the potential for pathogenic (disease-causing) bacteria to be present.

Host sources of fecal contamination in the Port Jefferson Harbor complex were assessed based on bacterial *Bacteroides* and *Helicobacter* microbial source tracking markers. Overall, human contributions were ubiquitous in receptor samples; canine and waterfowl markers were prevalent in surface water source samples in Port Jefferson Harbor and Setauket Harbor and in receptor samples in Conscience Bay. By evaluating the microbial source tracking markers alongside fecal coliform bacteria data and land-use information, geographical sources of fecal contamination discharging from the culverts and outfalls sampled as part of this study were better differentiated.

Among the potential sources of fecal contaminated water contributing to the Port Jefferson Harbor complex—groundwater, pond and wetland drainage, stormwater, marinas (boats), and the Port Jefferson sewage treatment plant—pond and wetland drainage and stormwater, direct and from stormwater conveyances, were the most likely transport mechanism of fecal contamination into the Port Jefferson Harbor complex. The most substantial source of fecal contamination to the Port Jefferson Harbor complex was found to be discharge from sites draining ponds and wetlands, particularly during the summer months when wildlife is more concentrated and tourism peaks. Fecal coliform bacteria at these site types are increased by stormwater runoff, which is another substantial source. Sites with high fecal coliform bacteria in the summer that is exacerbated by stormwater include the Culvert North of Shore Road, the Culvert North of 25A, Old Mill Creek and Mill Pond to Conscience Bay sites. Stormwater contributions of high fecal coliform bacteria can also be seen at the Outfall at Danfords Marina site.

Of the sites sampled for this study, four had persistently high fecal coliform bacteria concentrations in the summer, two of which had a consistent presence of human (HF183) and canine (BacCan) microbial source tracking markers (Old Mill Creek and Culvert North of State Route 25A). The Culvert North of State Route 25A, the Culvert North of Shore Road, the Old Mill Creek Culvert, and the Mill Pond Culvert to Conscience Bay sites were identified as sites that contributed a substantial source of fecal contamination to the Port Jefferson Harbor complex. Low concentrations of HF183 within Port Jefferson Harbor coupled with low to no detections of fecal coliform bacteria suggest that boats are not substantially contributing to fecal coliform bacteria. The absence of fecal coliform bacteria in groundwater samples that tested positive for the human microbial source tracking marker indicates that water from septic systems influences the harbor; however, it may not contribute to the elevated fecal coliform bacteria often detected. Further, the sandy sediment alongside Port Jefferson Harbor is unlikely to contribute fecal coliform bacteria when resuspended in the water column through tidal shifts or boat activity.

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Appendix 1. Sample Collection at Port Jefferson and Setauket Harbors on Long Island, New York

Table 1.1. Locations where samples were collected in Port Jefferson Harbor and Setauket Harbor on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.

[Samples collected include blanks and replicates. Data are from the National Water Information System (U.S. Geological Survey, 2020). Sample conditions of wet and dry indicate whether a sample was influenced by storm or nonstorm conditions, respectively. ID, identification number; EST, Eastern standard time]

Station name	Station ID	Date	Time (EST)	Sample type	Sample condition	Remarks
Conscience Bay Narrows	405806073062701	6/7/2018	848	Receptor	Dry	
Port Jefferson Harbor at Strongs Neck	405745073061801	6/7/2018	854	Receptor	Dry	
Culvert North of State Route 25A	405637073060601	6/7/2018	900	Source	Dry	
Mouth of Setauket Harbor	405731073054701	6/7/2018	918	Receptor	Dry	
Mid-West Port Jefferson Harbor	405744073053201	6/7/2018	923	Receptor	Dry	
Mouth of Pirates Cove	405800073044401	6/7/2018	947	Receptor	Dry	
Culvert North of Shore Road	405701073054101	6/7/2018	1000	Source	Dry	
Sewage Treatment Plant Outfall	405657073042601	6/7/2018	1027	Source	Dry	
Old Mill Creek Culvert	405605073041201	6/7/2018	1210	Source	Dry	
Culvert North of State Route 25A	405637073060601	7/18/2018	815	Source	Wet	
Mid-West Port Jefferson Harbor	405744073053201	7/18/2018	841	Receptor	Wet	
Mouth of Setauket Harbor	405731073054701	7/18/2018	847	Receptor	Wet	
Port Jefferson Harbor at Strongs Neck	405745073061801	7/18/2018	852	Receptor	Wet	
Conscience Bay Narrows	405806073062701	7/18/2018	900	Receptor	Wet	
Culvert North of Shore Road	405701073054101	7/18/2018	900	Source	Wet	
Mouth of Pirates Cove	405800073044401	7/18/2018	910	Receptor	Wet	
Sewage Treatment Plant Outfall	405657073042601	7/18/2018	916	Source	Wet	
Old Mill Creek Culvert	405605073041201	7/18/2018	940	Source	Wet	
Old Mill Creek Culvert	405605073041201	7/18/2018	941	Source	Wet	Replicate
Outfall near Danfords Marina	405652073040901	7/18/2018	1000	Source	Wet	
Mid Setauket Harbor	405659073061001	7/18/2018	1130	Receptor	Wet	
Public Beach and Dog Park	405704073040101	11/19/2018	1215	Source	GW	Groundwater
Public Beach and Dog Park	405704073040101	11/19/2018	1230	Source	Sed	Sediment
Walnut Beach	405714073050501	11/26/2018	1100	Source	GW	Groundwater
Culvert North of State Route 25A	405637073060601	2/19/2019	1020	Source	Dry	
Culvert North of Shore Road	405701073054101	2/19/2019	1120	Source	Dry	
Old Mill Creek Culvert	405605073041201	2/19/2019	1205	Source	Dry	
Conscience Bay Narrows	405806073062701	2/19/2019	1246	Receptor	Dry	
Port Jefferson Harbor at Strongs Neck	405745073061801	2/19/2019	1254	Receptor	Dry	
Mouth of Setauket Harbor	405731073054701	2/19/2019	1326	Receptor	Dry	
Mid-West Port Jefferson Harbor	405744073053201	2/19/2019	1330	Receptor	Dry	
Mouth of Pirates Cove	405800073044401	2/19/2019	1335	Receptor	Dry	
Sewage Treatment Plant Outfall	405657073042601	2/19/2019	1341	Source	Dry	
Culvert North of State Route 25A	405637073060601	4/1/2019	910	Source	Wet	
Culvert North of State Route 25A	405637073060601	4/1/2019	915	Source	Wet	Blank
Sewage Treatment Plant Outfall	405657073042601	4/1/2019	1005	Source	Wet	

Table 1.1. Locations where samples were collected in Port Jefferson Harbor and Setauket Harbor on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.—Continued

[Samples collected include blanks and replicates. Data are from the National Water Information System (U.S. Geological Survey, 2020). Sample conditions of wet and dry indicate whether a sample was influenced by storm or nonstorm conditions, respectively. ID, identification number; EST, Eastern standard time]

Station name	Station ID	Date	Time (EST)	Sample type	Sample condition	Remarks
Culvert North of Shore Road	405701073054101	4/1/2019	1020	Source	Wet	
Mouth of Pirates Cove	405800073044401	4/1/2019	1022	Receptor	Wet	
Mouth of Setauket Harbor	405731073054701	4/1/2019	1031	Receptor	Wet	
Mid-West Port Jefferson Harbor	405744073053201	4/1/2019	1036	Receptor	Wet	
Port Jefferson Harbor at Strongs Neck	405745073061801	4/1/2019	1048	Receptor	Wet	
Conscience Bay Narrows	405806073062701	4/1/2019	1052	Receptor	Wet	
Old Mill Creek Culvert	405605073041201	4/1/2019	1115	Source	Wet	

Table 1.2. Data summary of all samples collected in Port Jefferson Harbor and Setauket Harbor on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.

[Samples collected include blanks and replicates. Bacterial genetic markers are human-associated *Bacteroides* (HF183), ruminant-associated *Bacteroides* (Rum2Bac), waterfowl-associated *Helicobacter* (GFD), and canine-associated *Bacteroides* (BacCan) markers. Station data are available from the National Water Information System web interface (U.S. Geological Survey, 2020). *Bacteroides* samples were analyzed by the U.S. Geological Survey Ohio Microbiology Laboratory. Fecal coliform bacteria samples were analyzed by the Suffolk County Department of Health Services Public and Environmental Health Laboratory, unless denoted with a dagger (†), which indicates the sample was analyzed by the New York State Department of Environmental Conservation Marine Laboratory. Bacterial genetic marker values in bold indicate that the concentration was greater than the reporting limit; values preceded by a less than (<) symbol indicate the reporting limit for a given assay when a nondetect occurred. EST, Eastern standard time; copies/100 mL, copies per 100 milliliters; MPN/100 mL, most probable number per 100 milliliters; *, copies of genetic marker per gram dry weight; E, estimated; b, concentration was greater than the limit of quantification but less than the reporting limit; ~, duplicate qPCR results do not agree; V, result may be affected by contamination; c, contamination was found in a blank sample and was used to appropriately qualify associated samples; —, assay was not performed]

Station name	Date	Time (EST)	HF183 (copies/100 mL)	Rum2Bac (copies/100 mL)	GFD (copies/100 mL)	BacCan (copies/100 mL)	Fecal coliform (MPN/100 mL)
Conscience Bay Narrows	6/7/2018	848	<1,100	<1,880	<540	E~2,000	<20
Port Jefferson Harbor at Strongs Neck	6/7/2018	854	Eb~290	<2,300	<650	<940	<20
Culvert North of State Route 25A	6/7/2018	900	46,000	<3,200	<930	5,900	800
Mouth of Setauket Harbor	6/7/2018	918	<260	<2,300	<650	<940	<20
Mid-West Port Jefferson Harbor	6/7/2018	923	<260	<2,300	<650	<940	<20
Mouth of Pirates Cove	6/7/2018	947	<260	<2,300	<650	<940	20
Culvert North of Shore Road	6/7/2018	1000	<260	<2,300	8,300	12,000	300
Sewage Treatment Plant Outfall	6/7/2018	1027	7,000	<2,300	<650	Eb~990	20
Old Mill Creek Culvert	6/7/2018	1210	Vc19,000	<2,510	E~3,030	<1,040	800
Culvert North of State Route 25A	7/18/2018	815	9,600	<3,800	Eb2,400	21,000	3,000
Mid-West Port Jefferson Harbor	7/18/2018	841	Eb~230	<1,900	<540	<780	—
Mouth of Setauket Harbor	7/18/2018	847	Eb380	<1,900	<540	<780	—
Port Jefferson Harbor at Strongs Neck	7/18/2018	852	<220	<1,900	<540	<780	—
Conscience Bay Narrows	7/18/2018	900	E~930	<1,900	<540	<780	—
Culvert North of Shore Road	7/18/2018	900	<220	5,700	E~1,400	10,000	800
Mouth of Pirates Cove	7/18/2018	910	Eb380	<1,900	<540	<780	—
Sewage Treatment Plant Outfall	7/18/2018	916	3,200	<1,900	<540	<780	43†
Old Mill Creek Culvert	7/18/2018	940	840	<1,880	<540	3,700	3,000
Old Mill Creek Culvert	7/18/2018	941	2,440	<3,130	<900	E~11,700	3,000
Outfall near Danfords Marina	7/18/2018	1000	Eb~280	<1,900	<540	<780	1,300
Mid Setauket Harbor	7/18/2018	1130	<360	<1,880	<540	<780	—
Public Beach and Dog Park	11/19/2018	1215	E~600	<1,900	Eb650	<780	<3†
Public Beach and Dog Park	11/19/2018	1230	Eb100*	<2,100*	680*	Eb200*	—
Walnut Beach	11/26/2018	1100	<220	<1,900	<540	<780	<20
Culvert North of State Route 25A	2/19/2019	1020	4,400	<1,900	<540	Eb1,200	20
Culvert North of Shore Road	2/19/2019	1120	740	<1,900	3,400	7,700	20
Old Mill Creek Culvert	2/19/2019	1205	<220	<1,900	<540	<780	<18
Conscience Bay Narrows	2/19/2019	1246	E~600	<1,900	<540	<780	<18
Port Jefferson Harbor at Strongs Neck	2/19/2019	1254	Eb~290	<1,900	<540	<780	<18
Mouth of Setauket Harbor	2/19/2019	1326	<220	<1,900	Eb~570	<780	<18
Mid-West Port Jefferson Harbor	2/19/2019	1330	Eb~410	<1,900	<540	<780	<18
Mouth of Pirates Cove	2/19/2019	1335	Eb290	<1,900	<540	<780	<18
Sewage Treatment Plant Outfall	2/19/2019	1341	3,600	<1,900	<540	<780	<18

Table 1.2. Data summary of all samples collected in Port Jefferson Harbor and Setauket Harbor on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.—Continued

[Samples collected include blanks and replicates. Bacterial genetic markers are human-associated *Bacteroides* (HF183), ruminant-associated *Bacteroides* (Rum2Bac), waterfowl-associated *Helicobacter* (GFD), and canine-associated *Bacteroides* (BacCan) markers. Station data are available from the National Water Information System web interface (U.S. Geological Survey, 2020). *Bacteroides* samples were analyzed by the U.S. Geological Survey Ohio Microbiology Laboratory. Fecal coliform bacteria samples were analyzed by the Suffolk County Department of Health Services Public and Environmental Health Laboratory, unless denoted with a dagger (†), which indicates the sample was analyzed by the New York State Department of Environmental Conservation Marine Laboratory. Bacterial genetic marker values in bold indicate that the concentration was greater than the reporting limit; values preceded by a less than (<) symbol indicate the reporting limit for a given assay when a nondetect occurred. EST, Eastern standard time; copies/100 mL, copies per 100 milliliters; MPN/100 mL, most probable number per 100 milliliters; *, copies of genetic marker per gram dry weight; E, estimated; b, concentration was greater than the limit of quantification but less than the reporting limit; ~, duplicate qPCR results do not agree; V, result may be affected by contamination; c, contamination was found in a blank sample and was used to appropriately qualify associated samples; —, assay was not performed]

Station name	Date	Time (EST)	HF183 (copies/100 mL)	Rum2Bac (copies/100 mL)	GFD (copies/100 mL)	BacCan (copies/100 mL)	Fecal coliform (MPN/100 mL)
Culvert North of State Route 25A	4/1/2019	910	8,000	<1,900	<540	^E ~ 1,700	45
Culvert North of State Route 25A	4/1/2019	915	<220	<1,900	<540	<780	<18
Sewage Treatment Plant Outfall	4/1/2019	1005	1,400	<1,900	<540	<780	20
Culvert North of Shore Road	4/1/2019	1020	<220	<1,900	1,900	24,000	330
Mouth of Pirates Cove	4/1/2019	1022	^E b 540	<1,900	<540	<780	<18
Mouth of Setauket Harbor	4/1/2019	1031	<220	<1,900	<540	<780	<18
Mid-West Port Jefferson Harbor	4/1/2019	1036	870	<1,900	<540	<780	<18
Port Jefferson Harbor at Strongs Neck	4/1/2019	1048	^E ~ 980	<1,900	<540	<780	<18
Conscience Bay Narrows	4/1/2019	1052	<220	<1,900	<540	<780	<18
Old Mill Creek Culvert	4/1/2019	1115	^E b ~ 280	<2,300	3,300	2,400	20

Reference Cited

U.S. Geological Survey, 2020, USGS water data for the nation:
U.S. Geological Survey National Water Information System
database, accessed July 31, 2020, at [https://doi.org/10.5066/
F7P55KJN](https://doi.org/10.5066/F7P55KJN).

Appendix 2. Sample Collection in Conscience Bay on Long Island, New York

Table 2.1. Locations where samples were collected in Conscience Bay on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.

[Samples collected include blanks and replicates. Data are from the National Water Information System (U.S. Geological Survey, 2020). Sample conditions of wet and dry indicate whether a sample was influenced by storm or nonstorm conditions, respectively. ID, identification number; EST, Eastern standard time]

Station name	Station ID	Date	Time (EST)	Sample type	Sample condition	Remarks
Mill Pond at Culvert to Conscience Bay	405649073065701	9/13/2018	900	Source	Dry	
Conscience Bay at Mouth of Tidal Creek	405801073070901	9/13/2018	1015	Receptor	Dry	
Conscience Bay Northwest	405737073073001	9/13/2018	1035	Receptor	Dry	
Conscience Bay at Mouth of the Narrows	405751073071101	9/13/2018	1055	Receptor	Dry	
Conscience Bay Northeast	405739073070401	9/13/2018	1110	Receptor	Dry	
Mill Pond at Culvert to Conscience Bay	405649073065701	9/26/2018	1000	Source	Wet	
Mill Pond at Culvert to Conscience Bay	405649073065701	9/26/2018	1001	Source	Wet	Replicate
Conscience Bay at Mouth of Tidal Creek	405801073070901	9/26/2018	1120	Receptor	Wet	
Conscience Bay Northwest	405737073073001	9/26/2018	1140	Receptor	Wet	
Conscience Bay at Mouth of the Narrows	405751073071101	9/26/2018	1200	Receptor	Wet	
Conscience Bay Northeast	405739073070401	9/26/2018	1215	Receptor	Wet	
Mill Pond at Culvert to Conscience Bay	405649073065701	4/9/2019	925	Source	Wet	
Mill Pond at Culvert to Conscience Bay	405649073065701	4/9/2019	927	Source	Wet	Blank
Conscience Bay at Mouth of Tidal Creek	405801073070901	4/9/2019	1050	Receptor	Wet	
Conscience Bay at Mouth of Tidal Creek	405801073070901	4/9/2019	1052	Receptor	Wet	Replicate
Conscience Bay Northwest	405737073073001	4/9/2019	1115	Receptor	Wet	
Conscience Bay at Mouth of the Narrows	405751073071101	4/9/2019	1130	Receptor	Wet	
Conscience Bay Northeast	405739073070401	4/9/2019	1140	Receptor	Wet	
Mill Pond at Culvert to Conscience Bay	405649073065701	5/9/2019	540	Source	Dry	
Mill Pond at Culvert to Conscience Bay	405649073065701	5/9/2019	545	Source	Dry	Replicate
Mill Pond at Culvert to Conscience Bay	405649073065701	5/9/2019	550	Source	Dry	Blank
Conscience Bay at Mouth of Tidal Creek	405801073070901	5/9/2019	700	Receptor	Dry	
Conscience Bay Northwest	405737073073001	5/9/2019	715	Receptor	Dry	
Conscience Bay at Mouth of the Narrows	405751073071101	5/9/2019	725	Receptor	Dry	
Conscience Bay Northeast	405739073070401	5/9/2019	745	Receptor	Dry	

Table 2.2. Data summary of all samples collected in Conscience Bay on Long Island, New York, for bacterial genetic markers and fecal coliform analysis.

[Samples collected include blanks and replicates. Bacterial genetic markers are human-associated *Bacteroides* (HF183), ruminant-associated *Bacteroides* (Rum2Bac), waterfowl-associated *Helicobacter* (GFD), and canine-associated *Bacteroides* (BacCan) markers. Station data are from the National Water Information System (U.S. Geological Survey, 2020). *Bacteroides* samples were analyzed by the U.S. Geological Survey Ohio Microbiology Laboratory. Fecal coliform bacteria samples were analyzed by the Suffolk County Department of Health Services Public and Environmental Health Laboratory. Bacterial genetic marker values in bold typeface are indicative of a concentration greater than the reporting limit; values preceded by a less than (<) symbol indicate the reporting limit for a given assay when a nondetect occurred; values preceded by a greater than (>) symbol indicate the upper reporting limit for a given assay. EST, Eastern standard time; copies/100 mL, copies of genetic marker per 100 milliliters; MPN/100 mL, most probable number per 100 milliliters; E, estimate; b, concentration was greater than the limit of quantification but less than the reporting limit; ~, duplicate qPCR results do not agree; —, assay was not performed]

Station name	Date	Time (EST)	HF183 (copies/100 mL)	Rum2Bac (copies/100 mL)	GFD (copies/100 mL)	BacCan (copies/100 mL)	Fecal coliform (MPN/100 mL)
Mill Pond at Culvert to Conscience Bay	9/13/2018	900	<660	<5,600	E-4,800	28,000	5,000
Conscience Bay at Mouth of Tidal Creek	9/13/2018	1015	<530	<4,500	<1,300	<1,900	2,400
Conscience Bay Northwest	9/13/2018	1035	<260	<2,300	<650	<940	800
Conscience Bay at Mouth of the Narrows	9/13/2018	1055	<260	<2,300	<650	<940	300
Conscience Bay Northeast	9/13/2018	1110	<260	<2,300	<650	<940	500
Mill Pond at Culvert to Conscience Bay	9/26/2018	1000	<440	<3,800	<1,100	5,300	5,000
Mill Pond at Culvert to Conscience Bay	9/26/2018	1001	Eb-1,100	<4,500	4,100	110,000	1,600
Conscience Bay at Mouth of Tidal Creek	9/26/2018	1120	Eb470	<2,300	3,300	5,500	2,400
Conscience Bay Northwest	9/26/2018	1140	<260	<2,300	<650	Eb-1,700	170
Conscience Bay at Mouth of the Narrows	9/26/2018	1200	Eb390	<2,300	2,500	E-4,500	1,300
Conscience Bay Northeast	9/26/2018	1215	Eb460	<2,300	Eb1,300	E-2,900	500
Mill Pond at Culvert to Conscience Bay	4/9/2019	925	<260	<2,300	<650	<940	20
Mill Pond at Culvert to Conscience Bay	4/9/2019	927	<260	<2,300	<650	<940	<18
Conscience Bay at Mouth of Tidal Creek	4/9/2019	1050	<260	<2,300	Eb-740	<940	20
Conscience Bay at Mouth of Tidal Creek	4/9/2019	1052	<260	<2,300	<650	<940	110
Conscience Bay Northwest	4/9/2019	1115	<260	<2,300	<650	<940	<18
Conscience Bay at Mouth of the Narrows	4/9/2019	1130	<260	<2,300	<650	<940	<18
Conscience Bay Northeast	4/9/2019	1140	<260	<2,300	Eb-720	<940	<18
Mill Pond at Culvert to Conscience Bay	5/9/2019	540	<530	<4,500	<1,300	<1,900	45
Mill Pond at Culvert to Conscience Bay	5/9/2019	545	<1,100	<9,000	<2,600	<3,700	20
Mill Pond at Culvert to Conscience Bay	5/9/2019	550	<260	<2,300	<650	<940	<18
Conscience Bay at Mouth of Tidal Creek	5/9/2019	700	1,200	<3,000	Eb-1,700	E-4,800	790
Conscience Bay Northwest	5/9/2019	715	<260	<2,300	<650	<940	<18
Conscience Bay at Mouth of the Narrows	5/9/2019	725	<260	<2,300	<650	<940	<18
Conscience Bay Northeast	5/9/2019	745	Eb-360	<2,300	Eb-650	<940	<18

Reference Cited

U.S. Geological Survey, 2020, USGS water data for the nation: U.S. Geological Survey National Water Information System database, accessed July 31, 2020, at <https://doi.org/10.5066/F7P55KJN>.

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