CONNECTICUT SEA GRANT PROJECT REPORT FOR LIS PARTNERSHIP PROJECTS

Please complete this progress or final report form and return by the date indicated in the emailed progress report request from the Connecticut Sea Grant College Program. Fill in the requested information using your word processor (i.e., Microsoft Word), and e-mail the completed form to Syma Ebbin syma.ebbin@uconn.edu, Research Coordinator, Connecticut Sea Grant College Program. Do NOT mail or fax hard copies. Please try to address the specific sections below. If applicable, you can attach files of electronic publications when you return the form. If you have questions, please call Syma Ebbin at (860) 405-9278.

Please fill out all of the following that apply to your specific research or development project. Pay particular attention to goals, accomplishments, benefits, impacts and publications, where applicable.

Name of Submitter: Michael M. Whitney

Date of Report submission: 7/23/2026

Project #: _ Whitney R/CTP-57-CTNY _ Check one: [ ] Progress Report [X] Final report

Duration (dates) of entire project, including extensions: From [3/1/2023] to [6/15/2026].

Project Title or Topic: Tracking Pathogen Pathways and Fecal Bacteria Patterns for Public Beaches Suffering with Poor Water Quality Grades and Closures

Principal Investigator(s) and Affiliation(s):

1. Principal Investigator: Michael M. Whitney, Marine Sciences, University of Connecticut

2. Affiliate Investigator: Peter Linderoth, Save the Sound

A. COLLABORATORS AND PARTNERS:

Ledge Light Health District (LLHD)
Connecticut Department of Energy and Environmental Protection (CT DEEP)
City of New London Recreation Department
New England Science & Sailing
Project Oceanology

B. PROJECT GOALS AND OBJECTIVES:

Hypotheses (H):

H1) *There is strong hourly to daily variability in bacteria levels that is relevant to public health and swimming safety yet is missed by the current strategy for beach bacteria monitoring.*

H2) *There are episodic water pathways and environmental conditions favoring transport from pollution sources and bacterial proliferation that contribute to high beach bacteria events.*

Objectives (O):
O1) *To apply real-time field qPCR analysis techniques to measure high-resolution temporal and spatial patterns of fecal indicator bacteria (Enterococcus) at Green Harbor Beach and Rocky Neck State Park, public beaches suffering from bacteria issues, swim advisories, and closures.*
O2) *To analyze links between observed bacteria levels and environmental conditions (rain, tides, winds, temperatures, and river flow) to support source identification and bacteria forecasting.*
O3) *To quantify onshore/offshore transport and water retention times for beaches during varied summer forcing conditions with observations and high-resolution model results.*
O4) *To identify water transport pathways between likely bacteria sources and beaches with observations and high-resolution model results.*
O5) *To engage in experiential data-driven outreach on beach water quality issues with public school students, stewardship groups, environmental managers, and the general public.*

C. LIS Partnership CCMP ACTIONS:

This project was completed under the LIS Comprehensive Conservation and Management Plan (2015 LIS CCMP; 2020-2024 LIS CCMP Update), prior to the 2025 plan. The 2015 LIS CCMP articulates the need for projects like this. The research addresses:

1) Strategy 1-2b2 "Reduce human health risks through increased or targeted pathogen beach and embayment monitoring" and Implementation Action (IA) WW-19 "Encourage … adopt[ing] rapid bacterial detection technologies" are advanced by testing field qPCR methods.
2) Strategy 1-3b4 "Research, monitor, and assess pathogens, their sources and their impacts on water quality" and IA WW-31 "Assess sources of nutrient and pathogen contamination."
3) Strategy 3-1a3 "Connect/reconnect urban populations …to the Sound," Strategy 3-1b1 "Provide information products that educate communities about the health of LIS," and IA SC-8 "Raise awareness … about … water quality conditions that could impact human health."

D. LIS Partnership CCMP Performance Metrics:

This project was completed under the LIS Comprehensive Conservation and Management Plan (2015 LIS CCMP; 2020-2024 LIS CCMP Update), prior to the 2025 plan. The 2015 LIS CCMP does not have performance metrics associated with each implementation action. The list below includes relevant performance metrics from the 2025 LIS CCMP.

1. CWHW 3-2 Number of new pathogen detection methodologies developed
2. CWHW 3-2 Number of pathogen sources identified

3. IEP 2-1 Number of partners engaged in Partnership-supported environmental education networking and resource sharing opportunities

E. Quantity of LIS Partnership CCMP Metrics:

Quantity: 1 (CWHW 3-2 Number of new pathogen detection methodologies developed)
Quantity: 5 (CWHW 3-2 Number of pathogen sources identified)
Quantity: 3 (IEP 2-1 Number of partners engaged in Partnership-supported environmental education networking and resource sharing opportunities)

F. <u>PROGRESS</u>:

Progress on O1: The new Biomeme Franklin Thermocycler and associated supplies for real-time field quantitative polymerase chain reaction (qPCR) analysis were procured after the project started. Training, tutorials, and methods testing on the Biomeme Franklin Thermocycler were completed while preparing for year 1 summer sampling and completing the Quality Assurance Project Plan (QAPP) process. After the QAPP was approved on 8/10/23, weekly water sampling was initiated at Green Harbor Beach and Rocky Neck State Park. During the year 1 summer, samples at Green Harbor Beach were collected with 30 minutes of sample collection by LLHD. Samples at Rocky Neck State Park were collected for this project by CT DEEP staff at exactly the same time and location of the CT DEEP samples. Weekly sampling stopped when seasonal beach water quality monitoring ended on 8/23/23. Sample analysis with the real-time qPCR method returned results within 1-3 hours of sampling and the time to results decreased each week as the process was streamlined. During the sampling period, standard beach monitoring found that no samples were at or above management action levels (for swimming advisories or beach closures) for fecal indicator bacteria (FIB). Analysis with the Biomeme qPCR, however, detected FIB at some stations for some weeks at each beach. These results point to the real-time qPCR method being able to detect FIB levels below the management action threshold. The real-time qPCR assay also tests for human-specific fecal markers and registered positive results at some stations and weeks at each beach. The standard monitoring program does not measure for human-specific fecal indicators. Thus, the project provides new information about bacteria present in swimming waters.

During the year 2 summer, water samples were collected and analyzed at least weekly throughout the beach water quality monitoring season (5/20/24 to 8/26/24). Samples were collected coincident with CT DEEP collection at Rock Neck State Park and within an hour of LLHD sampling at Green Harbor Beach. Additional sampling was completed during rain events and bacteria-related swimming advisories at Green Harbor Beach. Sampling efforts also resolved tidal variability at both beaches. Bacteria detection results from the Biomeme qPCR have been quantitatively compared to bacteria levels measured with the EPA-approved standard Enterolert method. As in year 1, results indicate the Biomeme detects FIB below management action thresholds and below the detection limits of the Enterolert method. Paired Biomeme/Enterolert analysis of additional samples can yield more refined statistics on the comparison between the two methods. The higher-frequency sampling revealed tidal and daily fluctuations as large as weekly FIB monitoring reveals. These results

support hypothesis H1. Project results show days with high FIB levels that were missed by the monitoring program. Results also indicate how FIB levels changed during swim advisories. An added project year subsequently helped reveal more about these patterns.

During the year 3 summer, water samples were collected and analyzed throughout the beach water quality monitoring season at Rocky Neck State Park and Green Harbor Beach. New data and historical data point to July and August as the months most frequently having bacterial water quality issues. Paired Biomeme/Enterolert analysis indicates a weak level of correspondence between the two methods. Both measurements often detect bacteria when/where levels are high. On the other hand, the Biomeme methods often returns bacteria hits when the Enterolert does not (i.e. results are below the Enterolert detection threshold). A new step was water samples were taken to a 1:10 dilution prior to PCR analysis in the Biomeme Franklin Thermocycler. Dilution was done to see if results from the PCR analysis would align more closely with the Enterolert method by reducing positive hits with the PCR methods when levels were below the Enterolert detection limit. Unfortunately, no improvement was seen in the abilities of the Biomeme Frankin Thermocycler to obtain results consistent with the standard Enterolert testing method. We found that triplicate analysis helps overcome variability with Biomeme results for each sample. Analytical triplicates, however, raises costs. Furthermore, Biomeme has opted to shift their business model towards products catering to biodefense and healthcare. The ready-made assays and sample prep cartridges provided by Biomeme for water quality testing are now discontinued. Overall, our testing and experiences do not support pursuing Biomeme qPCR as a standard bacteria water quality method for beaches. Its main advantage of reducing time between sample and results is outweighed by Enterolert's ease of use, low-cost, and its already-standard status. Taking all of this into consideration, we conclude that using Biomeme for beach water quality testing is not a viable future method.

Progress on O2: Analysis linking high bacteria levels to environmental conditions has centered on historical data for all monitored saltwater beaches in Connecticut. The completed analysis relies on beach monitoring data served through the Sound Health Explorer (SHE) website and database. Environmental conditions were drawn from SHE for precipitation, nearby airports for winds, and nearby NOAA water level stations for tides. A journal article on this topic, written by graduate student Luke Glass as first author, has been published in *Ocean & Coastal Management*. The paper information is included in the next section. The abstract describes the research and emphasizes the importance of other environmental conditions besides precipitation (which is currently included in management plans):

> Swimming beaches along Long Island Sound (LIS) throughout Connecticut (CT) provide recreational value, but water quality issues can inhibit public coastal access. Swimming advisories or beach closures are instituted when enterococci concentrations, the fecal indicator bacteria for saltwater beaches, exceed 104 MPN/100 mL. Understanding the environmental conditions coinciding with high enterococci concentrations is important. Some CT beaches preemptively close based on precipitation volume, but other factors

can be influential. We hypothesize that high enterococci events are more likely with rain, onshore winds, and flood to high tidal stages. Enterococci and precipitation data for 74 CT beaches spanning 2003–2021 are accessed from the online Sound Health Explorer (SHE). Companion NOAA wind and tide data come from the nearest airport and tidal calculation station, respectively. Binary categorical analysis indicates rainy (wet) conditions account for 67 % of the high bacteria events (HBEs). Onshore winds and flood/high tides also individually are present for 67 % of the events. Combined categorical analysis indicates the wet, onshore wind, flood/high tide combination is the most prevalent (30 %). These findings point to adding winds and tides to online beach water quality sites such as SHE for retrospective analysis, highlighting their potential for triggering additional bacterial sampling to support management actions, and provides further context for understanding water quality patterns.

Progress on O3 and O4: Year 1 efforts to quantify onshore/offshore transport, water retention times, and transport pathways centered on model development. An idealized beach configuration with tides, winds, river flow, and tracer inputs (to track bacteria) was constructed, tested, and run using the Regional Ocean Modeling System (ROMS). Results emphasized conspicuous hourly variations in tracer concentrations as tidal conditions change. These model-based findings imply that current monitoring strategies likely under-sample the actual variability of beach water quality (consistent with project observational results). Model results also indicate how transport pathways and tracer distributions strongly vary with even moderate winds. Year 2 modeling efforts included the development and application of a realistic ROMS model of Rocky Neck Beach. Simulation results indicate an alongshore dilution of Bride Brook outflow water that is consistent with observed patterns of lowering FIB concentrations away from the mouth along Rocky Neck Beach. Simulation results also point to the importance of coastline curvature. Giants Neck is a coastal headland which favors retention of the bacteria-laden Bride Brook waters around the eastern end of Rocky Neck Beach. Model results will be included in a journal article and dissertation authored by graduate student Luke Glass.

Year 1 and 2 observational results clearly identify Bride Brook as the main bacteria source for Rocky Neck Beach. Drifter paths, water property (temperature and salinity) measurements, and bacteria patterns along the beach all align with this interpretation. Year 2 observations sampled a stormwater outfall at the south end of Green Harbor Beach during a heavy rain event. These results show exceedingly high FIB levels and identify this outfall as an important local bacteria source. The observational findings combined with modeling results support to hypothesis H2.

Year 3 model results for Rocky Neck emphasize the interaction of the Bride Brook buoyant plume with shallow bathymetry that increases exposure to bacteria on the western side of Rocky Neck State Park Beach. These results were presented at the Coastal and Estuarine Research Federation 2025 conference and the abstract describes some of the essential results:

Rocky Neck Beach in Connecticut regularly suffers from high enterococci concentrations, impeding beach access. A small freshwater brook on the eastern side of the beach

> delivers a small plume of fresh, bacteria-laden water directly onto the beachfront. Although long-term monitoring indicates spatially varying alongshore freshwater distribution, temporal changes in plume structure and mixing over a tidal cycle here remain unclear. A high-resolution hydrodynamic model, validated by high-frequency CTD transect sampling over the 2024 summer season, was used to understand bathymetric and tidal effects on the Rocky Neck plume, the freshwater retention mechanisms, and along and across-shore plume extent. Initial results imply sand bar morphology plays a key role in the retention of plume water close to the shoreline. Additionally, the nearfield plume is much fresher prior to offshore advection during a spring tide as opposed to neap. In all cases, alongshore plume influence is asymmetric, with western Rocky Neck beach remaining largely unaffected by the local outflow. These results provide greater insight into small-scale river plume behavior under different forcing conditions. Plume evolution also highlights the importance of tidal sampling to capture daily variability, particularly at beaches under the influence of localized freshwater sources.

Additional aspects of the modeling were presented at two subsequent conferences. The abstract from the presentation at the 2026 Ocean Sciences Meeting highlights the following methods and results:

> Rocky Neck Beach in Connecticut regularly suffers from high enterococci concentrations, impeding beach access. A small freshwater brook on the eastern side of the beach delivers a small plume of fresh, bacteria-laden water directly onto the beachfront. Although long-term monitoring indicates spatially varying alongshore freshwater distribution, temporal changes in plume structure and mixing over a tidal cycle here remain unclear. A high-resolution hydrodynamic model, motivated by high-frequency CTD transect sampling and in-situ discharge measurements from the 2024/25 summer seasons, was used to understand bathymetric and tidal effects on the Rocky Neck plume, freshwater retention mechanisms, and along/across-shore plume extent. Model results from the realistic scenario show the formation of eddies during the transition from ebb to flood over a naturally formed sandbar on the eastern side of the beach. These eddies break up the prototypical radial plume structure and retain freshwater along eastern Rocky Neck beach. Such eddies are absent during an ambient river salinity case, a no-discharge case, and are reduced in an idealized sloping bathymetry model run. A spring tide case shows a greater number of eddies with higher vorticity and is fresher prior to offshore advection as opposed to neap. In all cases, alongshore plume influence is asymmetrical, with western Rocky Neck beach lesser affected by the local outflow. Numerous simulations point to the sandbar acting as a driver to potential bacterial contamination on the eastern half but reducing this risk on the western half. These results provide greater insight into small-scale river plume behavior under different forcings. Plume evolution highlights the importance of tidal sampling to capture daily variability, particularly at beaches influenced by local freshwater sources. Future approaches to divert plume water must account for effects to beach morphology due to the sandbars role in preventing westward advection of bacterially loaded freshwater.

The poster at the Ocean Sciences Meeting was well received and was visited by British royalty. The abstract from the presentation at the 2026 Long Island Sound Research Conference overlaps in the motivation and adds in the effects of buoyancy variations with different river flow levels:

> Rocky Neck Beach in Connecticut regularly suffers from high enterococci concentrations, impeding beach access. A small freshwater brook on the eastern side of the beach delivers a small plume of fresh, bacteria-laden water directly onto the beachfront. Although long-term monitoring indicates spatially varying alongshore freshwater distribution, temporal changes in plume structure and mixing over a tidal cycle here remain unclear. A high-resolution hydrodynamic model, motivated by high-frequency CTD transect sampling and in-situ discharge measurements during the 2024/25 summer seasons, was used to understand buoyancy and tidal influences on the alongshore structure of the Rocky Neck plume. Model results from the neap tide scenario shows remnant plume waters to be perpetually present at the brook mouth. Spring tide results exhibit a large departure from the neap tide scenario during the low/flood stage. Greater alongshore momentum advects the plume farther west along the beachfront but fully mixes the plume waters away before the next plume pulse. Plume waters extend furthest west in the neutral buoyancy scenario and is deflected left and right out of the mouth by the tidal current. Reduced salinity gradients during a spring tide could therefore pose greater risks to bathers at western Rocky Neck. These results provide greater insight into small-scale river plume behavior under different forcings. Results highlight the importance of tidal sampling to capture daily variability. Results imply the need for CTD point sampling alongside water sample collection, and increased sampling frequency if the alongshore salinity gradient is small.

A related journal article manuscript and dissertation are in preparation.

For Green Harbor Beach, a stormwater outfall flanking the south side of the beach has been identified as a bacterial source. Sampling during a rain event occurring in year 2 measured very high bacteria levels from the outfall effluent. There is another outfall flanking the north side of the beach, but the end of the pipe is always submerged and has not been directly measured. Source tracking continued in 2026 by sampling stormwater before and during rain events. The drought during summer 2025 precluded sampling during wet conditions. The paired dry/wet measurements of catch basins in the vicinity of Green Harbor Beach revealed numerous contributing bacterial hot spots. Bacterial counts during wet conditions were an order of magnitude higher at all sampled locations. Particularly high values (more than 100 times action level) were detected at catch basins adjacent to nearby Green Harbor Park, athletic fields at Calkins Park, and some surrounding roads. Many locations are connected to the stormwater outfalls flanking Green Harbor Beach.

Progress on O5: A project website has been developed for providing project information to the general public; the web link is included in the next section. Key findings are included on the website. Additional information will continue to be added to the website in the coming year. Graduate student Luke Glass and PI Mike Whitney presented workshops to 5th and 6th

grade students during Marine Science Days at the UConn Avery Point Campus in May 2023 and 2024 (coordinated by Project Oceanology). The workshop focused on beach water quality issues and involved student activities on the beach to demonstrate onshore/offshore transport. Management outreach has progressed through partnerships with LLHD and CT DEEP. Outreach in New London was coordinated by Save the Sound. The oral presentation at the 2026 Long Island Sound Research Conference sparked discussions about possible management and community next steps to help beachgoer safety in light of known bacterial issues. Additional discussions with CT DEEP are anticipated.

Issues and Delays: The main delay occurring in year 1 was associated with the QAPP process. The first QAPP draft was submitted on 4/28/23. The EPA review was delivered on 6/9/23. A revised draft was submitted on 7/4/23. Additional review comments were sent on 7/19/23. A second revision was submitted on 7/25/23. The current version of the QAPP was approved and signed on 8/10/23. By this time most of the summer beach monitoring season had passed. Consequently, only a portion of the planned sampling program was completed in year 1. A full sampling season was completed in summer year 2. The year 2 sampling season successfully moved project objectives closer to completion. The first no-cost extension was requested to collect observations in summer 2025, continue modeling efforts, and analyze data.

The main analytical issue was translating real-time qPCR results into bacteria concentrations. The analysis returns presence/absence (i.e. detect/no-detect) results and additional information that ultimately can be translated into concentrations with appropriate calibration curves. Side-by-side comparison of qPCR results with standard Enterolert results has helped remedy this analytical challenge – additional samples will further refine the benchmarking of the field qPCR method. During summer 2025 a sample dilution approach was tested to reduced false positives of the qPCR method relative to the standard Enterolert. Based on our sampling and testing, the Enterolert is preferable to the Biomeme Franklin real-time qPCR method; the latter approach has large analytical variability and limitations that are obstacles to monitoring/managing applications.

A final 3.5-month no-cost extension was approved to complete stormwater outfall sampling and community outreach in New London. Drought conditions in 2025 made it hard to plan and conduct sampling during rainy (wet) conditions. To have the project team in place and ready to sample during wet conditions, the advanced weather forecast has to show likely widespread and heavy rains; scattered showers are not reliable enough to mobilize the sampling team. The final extension allowed for spring-season sampling to capture rainy conditions. The spring-season typically has more frequent large-scale rain events that facilitate planning and sampling operations. Stormwater outfall sampling and community outreach continued into June 2026 with the approved no-cost extension.

G. PROJECT PUBLICATIONS, PRODUCTS, PRESENTATIONS AND PATENTS:

Journal Articles (List URLs):

Glass, Luke, Michael M. Whitney, Peter Linderoth, 2025, Links between high fecal indicator bacteria levels and rain, wind, and tides at Connecticut beaches, *Ocean & Coastal Management*, *266, 107664*. https://doi.org/10.1016/j.ocecoaman.2025.107664

Conference Papers:

None

Proceedings or book chapters:

None

Web sites, Software, etc.:

https://cprime.uconn.edu/beachbacteria/

Technical Reports/Other Publications:

This Final Report

Other Products (including popular articles):

Long Island Sound Study, A New Approach to Beach Monitoring Could Improve Public Health in Connecticut, 8/16/2024, Long Island Sound Study website. https://longislandsoundstudy.net/2024/08/a-new-approach-to-beach-monitoring-could-improve-public-health-in-connecticut/

Publications planned / in progress:

Glass, L., Whitney, M., 2027, Tidal, bathymetric, and wind modification of a small-scale river plume and implications for beach water quality, *Estuarine and Continental Shelf Science*, in prep.

Glass, L., 2027, Wind, tide, and coastal effects on selected water quality issues and river plumes, Doctoral Dissertation, University of Connecticut, in prep.

Patents:

NONE

Presentations and Posters:

Glass, Luke (Presenter) and Michael M. Whitney, Multifarious Environmental Influences on High Fecal Indicator Bacteria Concentrations along Connecticut Beaches, Poster Presentation, 2024 Ocean Sciences Meeting, New Orleans LA, 2/20/2024, Estimated 6000 conference attendees.

Glass, Luke (Presenter). Multifarious Environmental Influences on High Fecal Indicator Bacteria Concentrations along Connecticut Beaches, Oral Presentation, UConn Marine Sciences Brown Bag Seminar, Groton CT, 3/6/2024, Estimated 40 attendees.

Glass, Luke (Presenter), Michael M. Whitney, and Peter Linderoth, Multifarious Environmental Factors Influencing FIB Concentrations on CT Beaches, Oral Presentation, 2024 Long Island Sound Research Conference, Port Jefferson NY, 5/15/2024, Estimated 200 conference attendees.

Glass, Luke (Presenter), Michael M. Whitney, and Parker Sallum, Beach morphology impacts on freshwater and enterococci distribution at Rocky Neck Beach, Connecticut, Oral Presentation, 2025 UConn Feng Colloquium, Groton CT, 5/15/2025, Estimated 80 conference attendees.

Glass, Luke (Presenter), Michael M. Whitney, and Parker Sallum, Tide and beach morphology impacts on freshwater and enterococci distribution at Rocky Neck Beach, Connecticut, Oral Presentation, Coastal and Estuarine Research Federation 2025 Conference, Richmond VA, 11/12/2025, Estimated 1000 conference attendees.

Glass, Luke (Presenter), Michael M. Whitney, and Parker Sallum, Tide and bathymetry impacts on freshwater and enterococci distribution at Rocky Neck Beach, Connecticut, Poster presentation, 2026 Ocean Sciences Meeting, Glasgow UK, 2/25/2026, Estimated 6000 conference attendees.

Glass, Luke (Presenter) and Michael M. Whitney, Tide and buoyancy influences on plume structure and enterococci distribution at Rocky Neck Beach, CT, Oral presentation, 2026 Long Island Sound Research Conference, Mystic CT, 06/04/26, Estimated 200 conference attendees.

H. FUNDS LEVERAGED:

None

I. STUDENTS:

*Note: **"Supported"** means supported by Sea Grant through financial or other means, such as Sea Grant federal, match, state and other leveraged funds. "**New**" students are those who **have not** worked on this project previously. "**Continuing**" students are those who **have** worked on this project previously. If a student volunteered time on this project, please use section G, below.*

Total number of **new** undergraduates who worked with you: 1
Total number of **new** Masters degree candidates who worked with you: 1
Total number of **new** Ph.D. candidates who worked with you: 1

Total number of **continuing** undergraduates who worked with you: 0
Total number of **continuing** Masters degree candidates who worked with you: 0
Total number of **continuing** Ph.D. candidates who worked with you: 1

Student Name: Luke Glass
Degree Sought*: M.S. / Ph.D.
Thesis or Dissertation Title: No title yet
Date of thesis completion: Not completed yet
Expected date of graduation: M.S. 05/2025 / Ph.D. 05/2027

*The student switched from M.S. only to M.S. / Ph.D. in 08/2023. The student is counted as both a Masters and Ph.D candidate in the table above.

Student Name: Parker Sallum
Degree Sought: B.S.
Expected date of graduation: 05/2027

J. VOLUNTEER HOURS:

Number of volunteers and their contribution to this project: 0
Total number of volunteer hours: 0

K. PICTORIAL:

Selected project photographs are included in a separate file submitted with this report. The project website (https://cprime.uconn.edu/beachbacteria/) also contains photographs.

L. HONORS AND AWARDS:

None

M. DATA MANAGEMENT PLANS:

No substantial modifications have been made related to data management.

FOR FINAL DEVELOPMENT AND RESEARCH GRANT REPORTS, PLEASE COMPLETE THIS SECTION:

N. PROJECT OUTCOMES AND IMPACTS

RELEVANCE OF PROJECT:

Swimming at public beaches provides recreational enjoyment, relief from the heat, and connections with coastal resources that promote environmental stewardship. The project focuses on human pathogen water quality issues at public beaches because swimming advisories and beach closures severely impair public access to coasts and the Long Island Sound (LIS). Study sites are Green Harbor Beach in New London, a municipal public beach, and Rocky Neck State Park, among the most visited Connecticut State Parks. These beaches regularly experience pathogen-related advisories and closures and receive C and D report card grades. For both public beaches, there is an urgent need to quantify variability in bacteria concentrations, link bacteria levels to an expanded set of environmental conditions, and identify transport pathways and connections to pollution sources. More generally, it is important to sustain and improve water quality at public beaches, as around 80% of the LIS coast is privately held. Furthermore, large gaps exist in official beach bacteria monitoring due to weekly sampling. New sampling strategies and techniques need to be tested.

RESPONSE:

This research project applies an innovative combination of observations, modeling, analysis, and outreach to address these issues. The hypotheses are: 1) There is strong hourly to daily

variability in bacteria levels that is relevant to public health and swimming safety yet is missed by the current strategy for beach bacteria monitoring; 2) There are episodic water pathways and environmental conditions favoring transport from pollution sources and bacterial proliferation that contribute to high bacteria events at beaches. The project tests new field methods for determining bacteria levels to assess utility for future monitoring and participatory science. Bacteria measurements at the target beaches are made at higher frequency than standard monitoring to quantify tidal and daily variability. Historical high bacteria events are linked to precipitation, winds, and tidal stage. Observed and modeled connectivity are applied to bacterial source attribution. Modeling is used to track the movement of bacteria-laden water and characterize variability with different forcing conditions. Results inform water quality management with the aspirational goal of keeping beaches safely open most of the summer. Target audiences include environmental stewardship and management collaborators, K-12 students, and communities of the beach-going general public.

RESULTS:

Objective O1 has the dual purpose of applying new real-time field qPCR analysis techniques and measuring bacteria levels at higher temporal and spatial resolution than standard monitoring. The new Biomeme Franklin Thermocycler was tested in both outdoor battery-operated field mode and an indoor plugged-in laboratory setting. The instrument functioned in both settings. The climate control of the laboratory setting appears to somewhat reduce variability among analytical triplicates. In both settings, a stable non-moving platform is recommended. Biomeme qPCR bacteria results were compared against water-sample analysis with Enterolert, an EPA-approved standard method that relies on detecting fluorescence of a nutrient indicator in the presence of an incubated bacteria sample. The paired Biomeme/Enterolert analysis indicates a limited correspondence (see Table below).

Table: *Biomeme/Enterolert paired analysis results.*

Paired sample analysis	Samples from Rocky Neck and Green Harbor Beach	Summer 2024 samples
Biomeme No-detect & Enterolert No-detect **26 (33%)**	Biomeme Detect & Enterolert No-Detect 19 (24%)	*Biomeme No-Detect: 41* *Biomeme Detect: 38* *Total: 79*
Biomeme No-Detect & Enterolert Detect 15 (19%)	Biomeme Detect & Enterolert Detect **19 (24%)**	*Enterolert No-Detect: 45* *Enterolert Detect: 34* *Total: 79*

For 57% of the paired samples, both methods are consistent in the sense that the both either registered no-detects (pointing to low bacteria levels) or detects (indicating measurable bacteria levels). The remaining 43% of samples yielded inconsistent results, with false positives and negatives. Given that Enterolert is an approved standard method, the limited correspondence between methods is an obstacle for accepting Biomeme qPCR as an alternate method yielding comparable results. Subsequent testing of sample dilution prior to Biomeme analysis was conducted in an attempt to raise the Biomeme detection limit and reduce false

positives relative to the Enterolert method. Dilution, however, did not result in improved correspondence. Furthermore, we could not obtain a statistically reliable calibration curve to transform Biomeme results into quantitative bacterial counts analogous to the Enterolert method. Other drawbacks of the Biomeme method are analytical triplicates are recommended but increase analysis costs, training and the method are more involved, and Biomeme has discontinued the standard assay kits for bacterial water testing as the company has pivoted more towards biodefense and healthcare. Overall, our testing and experiences do not support pursuing Biomeme qPCR as a standard bacteria water quality method for beaches. Its main advantage of reducing time between sample and results is outweighed by Enterolert's ease of use, low-cost, and its already-standard status.

Results from Green Harbor Beach (using the Enterolert method) illustrate tidal and spatial variability in bacteria counts (see Table below). Standard monitoring measures bacterial levels once a week in the morning (around 9 AM) during whatever tidal stage is occurring at one station on the north end of the beach. Project results reveal a similar high amount of variability among tidal stages (during a single day) and among stations at different sections of the relatively short beach. In this example case, a bacteria count exceeding the 104 MPN/100 mL management threshold was detected at low tide at the north end of the beach, while other times and stations were below the threshold.

Table: *Bacteria counts (MPN/100 mL) from Enterolert method for samples taken at three Green Harbor Beach stations at four tidal stages on 7/10/2024.*

	South End	Middle	North End
Low tide	10	<10	717
Flood tide	52	31	52
High tide	63	52	41
Ebb tide	20	75	10

Another example that illustrates spatial variability is from Green Harbor Beach during a rain event (see Table below). The project team collected samples directly from an outfall at the south end of the beach (prior to entering and mixing with swimming waters) and also from three stations along the beach. Outfall effluent had exceedingly high bacteria concentrations that maxed out the Enterolert analysis range. These observations confirm this stormwater outfall as a bacteria source for Green Harbor Beach. Bacteria levels were many times higher than the management action level at all stations. Counts were three times higher at the north end than the south end, suggesting another bacteria source (potentially the submerged stormwater outfall at the north end of the beach). Ledge Light Health District (LLHD) sampled several hours later (at a different tidal stage) at only the north end as part of standard weekly monitoring. The LLHD reading was high enough to trigger a swimming advisory, but was several times lower than the value at the same station a few hours before.

Table: *Bacteria counts (MPN/100 mL) from Enterolert method for samples taken at three Green Harbor Beach stations at four tidal stages on 7/29/2024 during a 1.1 inch rain event.*

Collector	Time & Tide	South outfall	South End	Middle	North End
Project team	7:22 AM EDT Ebb tide	>24,196	3654	2247	12,033
LLHD monitoring	10:05 AM EDT Low tide	N/A	N/A	N/A	2000

These examples and additional results revealed tidal and daily fluctuations as large as the week-to-week variations that standard monitoring reveals. Project results also show days with high bacteria levels that were missed by the weekly monitoring program.

Objective O2 investigates links between observed bacteria levels and environmental conditions. Analysis centered on historical data for 74 monitored saltwater swimming beaches in Connecticut. Data are from the Sound Health Explorer online database and from online NOAA winds and tidal water levels. A journal article on this topic ("Links between high fecal indicator bacteria levels and rain, wind, and tides at Connecticut beaches", written by graduate student Luke Glass (as first author) and project principal investigators) has been published in *Ocean & Coastal Management*. Binary categorical analysis indicates rainy (wet) conditions account for two-thirds of the high bacteria events (see Figure below). Onshore winds and flood/high tides also individually are present for two-thirds of the events.

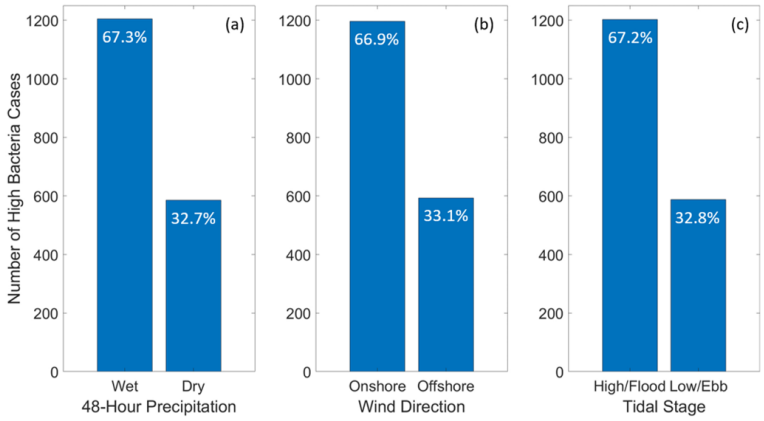


Figure: *Occurrence of high bacteria events (across 74 monitored Connecticut beaches) in relation to wet or dry conditions, locally onshore or offshore winds, or high/flood or low/ebb tidal stage (following Glass et al., 2025).*

Combined categorical analysis indicates the wet, onshore wind, flood/high tide combination is the most prevalent case (covering almost one-third of high bacteria events). These findings point to the utility of adding winds and tides to online beach water quality sites such as the Sound Health Explorer. Wind and tidal factors can be incorporated into decisions that trigger additional bacterial sampling and management actions, and provide further context for understanding water quality patterns.

Subsequent analysis of historical and new data (accessed through the Sound Health Explorer and with new project observations) has focused on patterns in the background bacteria levels at Rocky Neck Beach (see Figure below). Results indicate higher background levels in July and August.

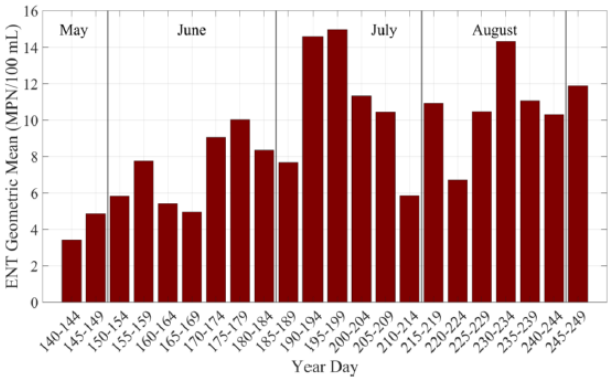


Figure: *Geometric mean bacteria counts (enterococci, ENT) for five-day bins across 2003-2025 summer seasons at all Rocky Neck Beach stations. Note that high bacteria events (with much higher counts) can occur throughout the season, but such events are averaged with many other low bacteria level conditions from other stations or years.*

Over the same years, high bacteria events (not shown) predominantly occur in July (44%) and August (33%), with the remainder occurring in June (19%) or the last week of May and first week of September (4%). July and August are the most impacted months and the times that typically have the most beachgoers.

Objectives O3 and O4 combine observations and modeling results to investigate transports and connectivity between bacteria sources and beach waters. Modeling focused on Rocky Neck Beach because of the presence of the Bride Brook outflow as a primary bacteria source. Bacteria observations clearly (and repeatedly) identify Bride Brook as the main bacteria source for Rocky Neck Beach. Drifter paths, water property (temperature and salinity) measurements, and bacteria patterns along the beach all align with this interpretation. Outflow behavior can be interpreted in the context of small-scale river plumes that transport buoyant freshwaters offshore and along the coast. As with many river plumes, the Bride Brook outflow is influenced by tides in several ways: influencing flow conditions through the mouth, affecting (and reversing) alongshore and across-shore flows, and enhancing mixing with ambient waters. The high-resolution simulation of the Bride Brook outflow in Rocky Neck Beach waters was accomplished with the Regional Ocean Modeling System (ROMS). Low-salinity water with a tidally varying outflow rate is imposed at the mouth, tidal elevations and currents are applied along offshore and lateral domain boundaries, and winds (when included) are imposed as spatially uniform surface stresses. A conservative passive tracer is included to track plume waters and infer distributions and conservative mixing of bacteria-laden plume waters. Results emphasize conspicuous hourly variations in tracer concentrations as tidal conditions change. These model-based findings imply that current monitoring strategies likely under-sample the actual variability of beach water quality. Plume-water distributions vary through high, ebb, low,

and flood tidal stages and also vary with neap, mean, and spring tidal amplitudes (see set of three Figures below). Concentrations are highest during ebb (near the source) and the concentrated plume grows radially throughout ebb to low tide. The concentrated ebb and low tide plume become smaller from neap, to mean, to spring tides due to stronger advecting tidal currents and increased mixing. Spring tides create a markedly different situation than other tidal conditions because the plume is swiftly swept alongshore and its signature is entirely mixed away throughout flood and high tide. In the neap and mean tide situations, the plume is more diffuse and blob-like (losing its organized expanding radial form) but still represents exposure to potentially high bacteria waters along the eastern part of Rocky Neck Beach.

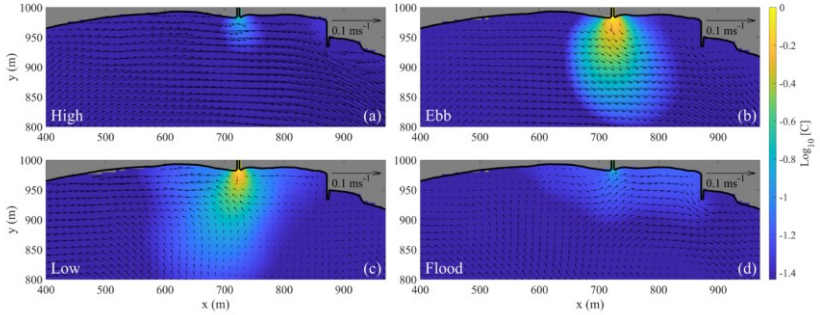


Figure: *Neap tide simulation results for Bride Brook outflow into Rocky Neck Beach waters. Shading indicates concentrations of the passive tracer tracking potentially bacteria-laden plume waters. Vector arrows show surface currents (subsampled for visualization purposes). Averages for high, ebb, low, and flood tidal stages are shown. Rocky Neck Beach extends farther west than graphing limits and the model domain extends farther in all directions.*

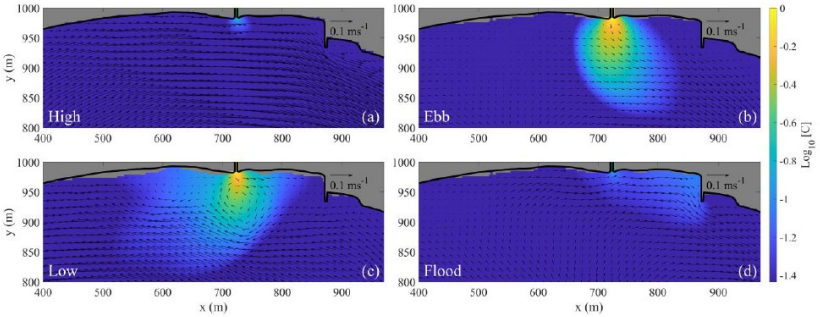


Figure: *Same as for previous figure, but for Mean tides.*

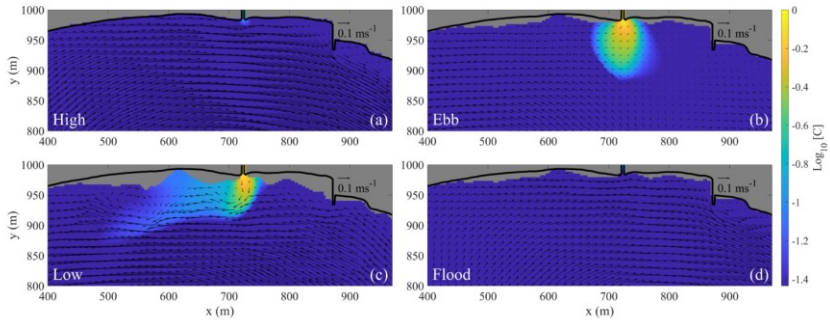


Figure: *Same as for previous figure, but for Spring tides.*

In general, simulation results indicate an alongshore dilution of Bride Brook outflow water that is consistent with observed patterns of lowering bacteria concentrations away from the mouth along Rocky Neck Beach. Modeling sensitivity studies (not shown) investigate the roles of additional factors. The presence of a large sandy shoal on the eastern end of Rocky Neck Beach modifies plume shape and increases retention of plume waters along the eastern end for some situations. Increasing outflow salinity (as happens during lower flow conditions typically later in summer) leads to reduced offshore transport and more transport to the east and west along the beach in shallow nearshore waters. These conditions extend bacteria exposure risks farther along the beach, particularly westward where there is more beach length to travel. Onshore winds tend to keep plume waters close to the coast and spread the alongshore reach of plumes waters. Overall, the simulated plume evolution highlights the importance of accounting for or at least noting tidal conditions and other environmental factors in bacteria monitoring. Furthermore, measuring water temperature and salinity at each Rocky Neck Beach monitoring stations can be helpful for connecting bacteria concentrations with Bride Brook outflow waters.

Green Harbor Beach has a confirmed bacteria source from a stormwater outfall at the south end of the beach (as described above). Project observations during a rain event also measured an exceedingly high bacteria concentration on the north end, next to a submerged stormwater outfall that is a likely bacteria source. Paired dry/wet measurements of catch basins in the vicinity of Green Harbor Beach revealed numerous contributing bacterial hot spots next to a park, athletic fields, and surrounding roads. Results collectively indicate that Green Harbor Beach can become awash in bacteria from these nearby sources. The source-to-beach connectivity is direct and immediate, particularly during rain events. There also may be contributions from remote sources. Overhaul of the stormwater infrastructure and undertaking bacteria mitigation measures on nearby public open space would help with bacteria issues.

Objective O5 centers on data-driven outreach to numerous audiences. A project website has been developed for providing project information to the general public. Key findings are included on the website. Workshops focusing on beach water quality issues were presented to 5th and 6th grade students during annual Marine Science Days at the UConn Avery Point Campus in coordination with Project Oceanology. Management outreach is progressing through partnerships with LLHD and CT DEEP. Outreach in New London is coordinated with Save the Sound. The oral presentation at the 2026 Long Island Sound Research Conference sparked discussions about possible management and community next steps to help beachgoer safety in light of known bacterial issues. Additional discussions and publications are anticipated.

Both Hypotheses are supported by observational and modeling results: *H1) There is strong hourly to daily variability in bacteria levels that is relevant to public health and swimming safety yet is missed by the current strategy for beach bacteria monitoring.* Tides are a major driver of hourly variability at both Green Harbor Beach and Rocky Neck Beach. Once-weekly sampling

does not account for tidal variability. Routine more-frequent monitoring resolving tidal variability likely is too time-intensive and cost-prohibitive. A way forward is adaptive sampling (resolving high frequency variability) during higher risk times such as after rain events or following measured high bacteria levels triggering swimming advisories. The current monitoring system has gaps that may increase public risks. *H2) There are episodic water pathways and environmental conditions favoring transport from pollution sources and bacterial proliferation that contribute to high beach bacteria events.* Green Harbor Beach is episodically dosed with high-bacteria waters from stormwater outfalls during rain events. Pathways are short and direct because outfalls flank the beach and catch basin sources are nearby. On Rocky Neck Beach transport pathways are affected by how the Bride Brook plume is modulated by tidal stage and spring-neap tidal cycles. The eastern end of the beach has the most exposure to high-bacteria waters. General analysis of Connecticut beaches indicates some key environmental conditions connected to high bacteria events are rain, onshore winds, and flood/high tides.

J. Stakeholder Summary

Swimming at public beaches provides recreational enjoyment, heat relief, and connections with coastal resources. Bacterial problems severely impair beach access, are a serious public health issue, and trigger swimming advisories and beach closures. There is an urgent need to quantify variability in bacteria concentrations, make links to environmental conditions, and identify primary pollution sources. Such analysis ultimately can lead to better safeguards for public health. This Long Island Sound Partnership project focuses on Green Harbor Beach (New London, CT) and Rocky Neck Beach in Rocky Neck State Park (East Lyme, CT). These beaches regularly experience pathogen-related advisories and closures and receive C and D grades on the Long Island Sound Report Card. This research project applies an innovative combination of observations, modeling, analysis, and outreach to address these issues.

Results at Green Harbor Beach indicate a stormwater outfall at the south end of the beach is a bacterial source. The submerged outfall at the north end also is a likely source. Catch basins surrounding the beach (near a park and athletic fields) also have high bacteria levels, particularly during rains. Sampling during different times of day and varying tidal stage indicate changes in bacteria levels that are missed by standard once-weekly monitoring.

Project results and state monitoring at Rocky Neck Beach indicate the Bride Brook outflow is the main bacterial pollution source, which primarily affects the eastern end of the beach. Many beachgoers spend time in this area. Project observations measured conditions near the Bride Brook mouth and tracked outflowing waters along the beach and offshore. Flow conditions and bacteria levels vary considerably as tides change. A simulation for the Bride Brook outflow into Rocky Neck Beach waters shows how the distribution of frequently bacteria-laden waters change with tidal conditions. Concentrated outflow waters occupy the most area during ebb and low tides. Neap tides favor higher concentrations than spring tides. Model results illustrate hourly variability in water distributions that can affect beach water quality. Once-weekly bacterial monitoring does not account for such variations.

Two decades of water quality data at monitored saltwater swimming beaches throughout Connecticut indicate that rain, winds, and tides are equally important factors for high bacteria events. Currently, only rain is considered as a management and monitoring factor. It would be beneficial to also consider winds and tides and to add these factors to online beach water quality sites such as the Sound Health Explorer.



Professor Mike Whitney taking water temperature and salinity measurements on Rocky Neck Beach while a CT DEEP seasonal water quality specialist collects a water sample for bacterial analysis (Luke Glass, East Lyme CT, 8/24/2023).



PhD Student Luke Glass measures the water temperature and salinity of the Bride Brook mouth on Rocky Neck Beach (Photo by Mike Whitney, East Lyme CT, 9/5/2025).



PhD Student Luke Glass releases the second of three GPS-tracked surface drifters tracking the Bride Brook outflow from the mouth into the waters offshore of Rocky Neck Beach (Photo by Mike Whitney, East Lyme CT, 9/5/2025).



Eastern entrance to Rocky Neck Beach along walkway over Bride Brook and under railway bridge (Photo by Mike Whitney, East Lyme CT, 8/14/23).



Beachgoers walking past bacteria warning sign and congregating near Bride Brook mouth (and its outflowing bacteria-laden waters) (Photo by Mike Whitney, East Lyme CT, 5/20/2024).



Bride Brook outflow on Rocky Neck Beach at low tide. Beachgoers are standing on sandbars and walking through shallow waters. (Photo by Mike Whitney, East Lyme CT, 7/1/2024).



Beachgoers walking next to and in stained bacteria-laden waters flowing from Bride Brook out to Rocky Neck Beach (Photo by Mike Whitney, East Lyme CT, 7/15/2024).



South end of Green Harbor Beach showing marina docks and covered stormwater outfall (on right side) (Photo by Mike Whitney, New London CT, 8/21/2023).



View of empty Green Harbor Beach during posted swimming advisory due to high bacteria levels (Photo by Mike Whitney, New London CT, 7/3/2024).



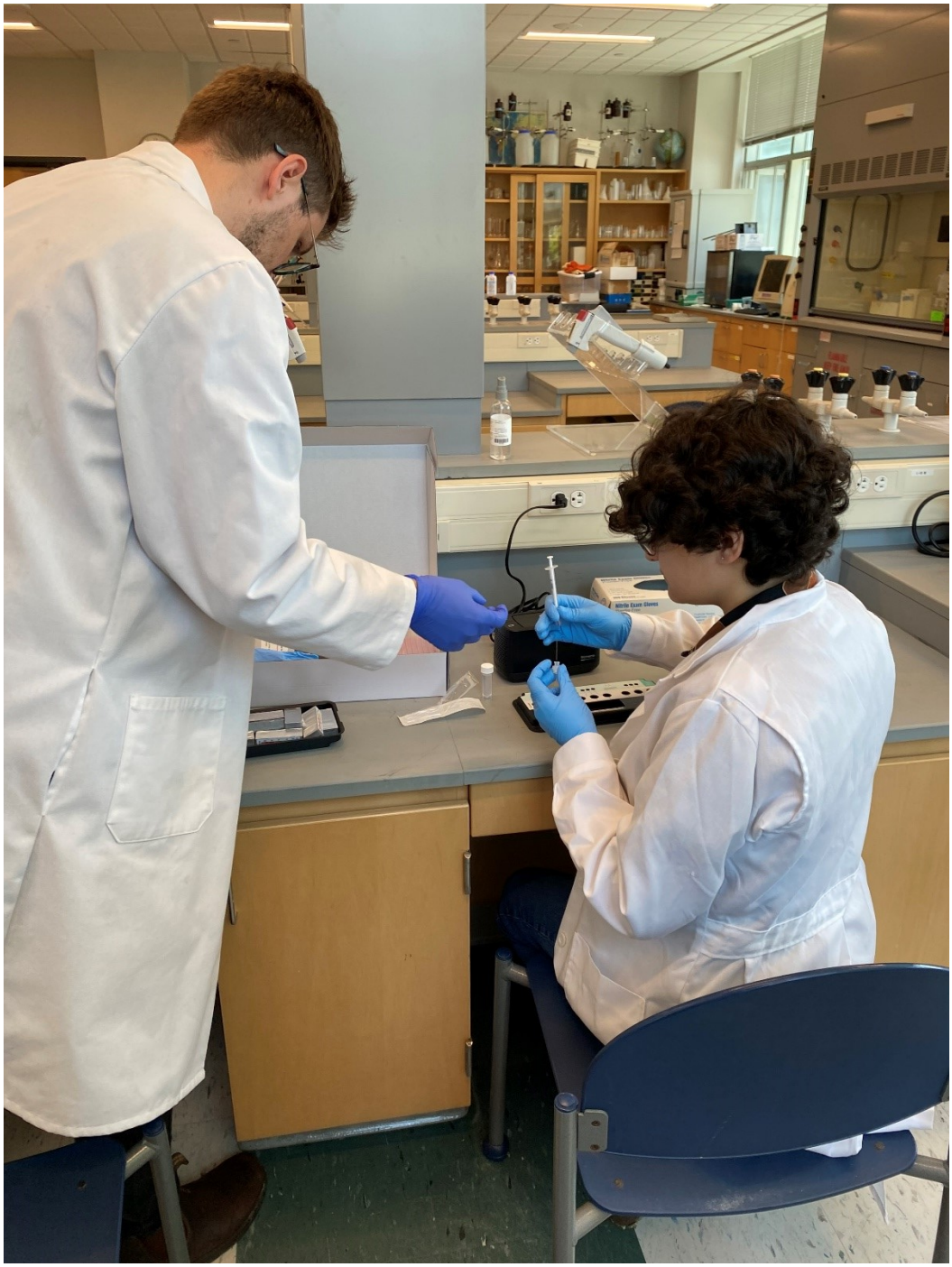
View of Green Harbor Beach looking northward bounded by marina wall. A submerged stormwater outfall runs parallel to the wall at the north end of the beach (Photo by Mike Whitney, New London CT, 7/10/2024).



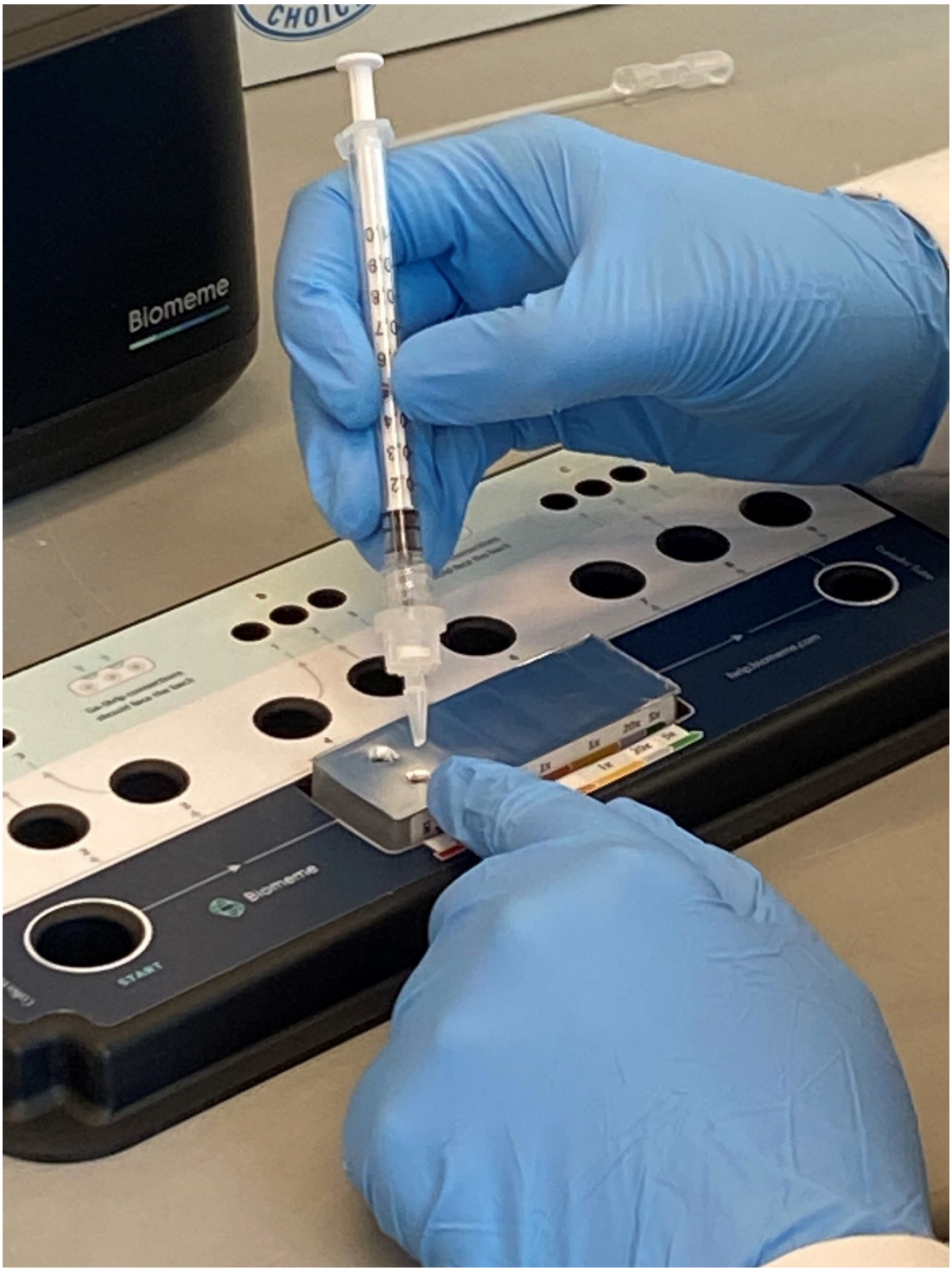
Stormwater with measured high bacteria levels exiting an outfall on the south side of Green Harbor Beach (Photo by Mike Whitney, New London CT, 7/29/2024).



PhD student Luke Glass processing a water sample for bacteria analysis with the Biomeme real-time qPCR, in battery-operated outdoor field mode (Photo by Mike Whitney, Groton CT, 8/14/2023).



PhD student Luke Glass assisting undergraduate student Parker Sallum in processing water samples for bacterial analysis with the Biomeme real-time qPCR, in a plugged-in laboratory setting (Photo by Mike Whitney, Groton CT, 5/28/2024).



Undergraduate student Parker Sallum progressing through bacterial analysis with a Biomeme test kit designed for enterococci and human fecal bacteria (Photo by Mike Whitney, Groton CT, 7/22/2026).



Undergraduate student Parker Sallum and PhD student Luke Glass using UV light to illuminate bacteria counts as part of the standard Enterolert method (Photo by Mike Whitney, Groton CT, 5/28/2024).