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Corolla Beach, North Carolina. S. Barash

Implementing the BEACH Act of 2000: *2022 Report to Congress*

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Acronym List

BEACH Act - Beaches Environmental Assessment and Coastal Health Act

BEACON – Beaches Advisory and Closure Online Notification

CWA – Clean Water Act

cyanoHABs - cyanobacterial harmful algal blooms

ddPCR – droplet digital polymerase chain reaction

EJ – environmental justice

EPA – Environmental Protection Agency

HABs – harmful algal blooms

HEP – Harbor and Estuary Program

NEP – National Estuary Program

NPS – National Park Service

ORD – Office of Research and Development

PIC – Pollution Identification and Correction

QAPP – Quality Assurance Program Plan

QMRA - Quantitative Microbial Risk Assessment

qPCR – quantitative polymerase chain reaction

RWQC - Recreational Water Quality Criteria

TAS – Treatment as a State

USACE – United States Army Corps of Engineers

Web-VB – Web-based version of Virtual Beach

Executive Summary

This report documents the recent progress that states, tribes, territories, the Environmental Protection Agency (EPA), and other federal agencies have made to implement the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000. Section 7 of the BEACH Act (33 U.S.C. § 1375a) requires EPA to publish reports to Congress on the implementation of the Act every four years.

Coastal beaches are one of our nation's natural treasures. They are important for recreation and connecting with nature and are an integral part of our national economy. According to the United States Census Bureau, 94.7 million people, or about 29.1% of the total U.S. population, lived in coastline counties in 2017.[1] The United States Lifesaving Association estimated there were more than 400 million visits to U.S. beaches in 2019.[2] Ocean-based tourism and recreation contributes an estimated $143 billion in gross domestic product to the national economy each year according to the National Oceanic and Atmospheric Administration.[3]

This report highlights EPA accomplishments since the 2018 BEACH Act Report to Congress:

- draft analytical methods for coliphage, an indicator of viral fecal contamination
- advances in qPCR methods providing same-day monitoring results
- the development of the Alternative Methods Calculator Tool
- recreational water quality criteria for cyanotoxins
- the development and release of the Sanitary Survey App, which is used to identify sources of fecal contamination and document harmful algal blooms
- the development of a web-based version of Virtual Beach software which predicts pathogen indicator levels
- a preliminary analysis to identify beaches near communities with possible environmental justice concerns

The report also details numerous programs and projects employed by the 39 states, tribes, and territories that receive BEACH Act grants to monitor coastal water quality and keep the public informed within current budgets and staff levels, while facing challenges caused or exacerbated by the COVID-19 pandemic and climate change.

[1] www2.census.gov/library/stories/2018/08/coastline-counties-list.xlsx
[2] http://arc.usla.org/Statistics/current.asp?Statistics=5
[3] https://coast.noaa.gov/states/fast-facts/tourism-and-recreation.html

Section 1. Introduction

On October 10, 2000, the BEACH Act was signed into law, amending the Clean Water Act (CWA). The BEACH Act was designed to address human health risks associated with water quality and swimming or similar water-contact activities in coastal recreational waters.

The presence of pathogens associated with fecal material at our nation's beaches is a public health concern. Beach waters can be contaminated with pathogens that cause a variety of illnesses. Such illnesses include diarrhea as well as respiratory, ear, eye, and skin infections. Sources of fecal contamination at our nation's beaches include wastewater collection systems and treatment plants, septic tanks, bathers, wildlife, urban stormwater, and runoff from coastal and shoreline development.

The BEACH Act addresses pathogens and pathogen indicators in coastal recreational waters, which are defined in section 502 of the CWA as the Great Lakes and marine coastal waters designated under CWA section 303(c) for swimming, bathing, surfing, or similar water-contact activities. The BEACH Act amended the CWA to address three significant areas:

- The BEACH Act added CWA section 303(i) which directs states that have coastal recreational waters to adopt new or revised recreational water quality standards by April 10, 2004, for pathogens and pathogen indicators for which EPA had published criteria under CWA section 304(a) – i.e., EPA's 1986 Bacteria Criteria Recommendations. CWA section 303(i) also directs EPA to promulgate standards for states that fail to establish standards as protective of human health as EPA's 1986 criteria. EPA promulgated the 1986 criteria for 35 states and territories in 2004.
- The BEACH Act added CWA sections 104(v) and 304(a)(9) which require EPA to conduct studies associated with pathogens and human health and to publish new or revised CWA section 304(a) criteria for pathogens and pathogen indicators based on those studies. Under CWA section 303(i)(1)(B), states that have coastal recreational waters are directed to adopt new or revised water quality standards for all pathogens and pathogen indicators to which EPA's new or revised CWA section 304(a) criteria are applicable by not later than three years after EPA's publication of the new or revised CWA section 304(a) criteria. EPA conducted over 35 studies to meet the requirements in 2010 (https://www.epa.gov/wqc/recreational-water-quality-criteria-and-methods#rec2) and published updated criteria in 2012. All jurisdictions receiving grants have adopted the 2012 criteria or equivalent in their water quality standards and are using appropriate notification values in their beach programs.
- The BEACH Act added CWA section 406 which authorizes EPA to award grants to states or local governments to develop and implement beach monitoring and notification programs. It also requires EPA to maintain state monitoring and notification data and make them available to the public. In addition, the BEACH Act amended section 518(e) of the CWA to authorize EPA to treat tribes in the same manners as states for the purposes of section 406; therefore, EPA is authorized to award grants to tribes. EPA continues to maintain and upgrade its publicly available Beaches Advisory and Closure Online Notification (BEACON) system (https://www.epa.gov/waterdata/beacon-20-beach-advisory-and-closing-online-notification) where states, tribes, and territories report their monitoring and notification data. EPA currently awards grants to 30 states, four tribes with Treatment as a State (TAS) status, and five territories. EPA works to ensure that eligible tribes with TAS status that adopt water quality standards are informed of the BEACH Act grant application process.

Section 7 of the BEACH Act directs EPA to include the following information in this report:

- Recommendations concerning the need for additional water quality criteria for pathogens and pathogen indicators and other actions that should be taken to improve the quality of coastal recreation waters.

- Recommendations on improvements to methodologies and techniques for monitoring of coastal recreation waters.
- An evaluation of federal, state, and local efforts to implement the Act.

Lake Michigan. M. Martinez

Section 2. Water Quality Criteria Development and Other Actions to Improve the Quality of Coastal Recreation Waters

The BEACH Act directs EPA to provide recommendations concerning the need for additional water quality criteria for pathogens and pathogen indicators and other actions that should be taken to improve the quality of coastal recreation waters. This section includes an introduction to recreational water quality criteria and describes new criteria, criteria under development, and new tools that EPA has developed since the 2018 report to Congress.

Certain pathogens, such as bacteria and viruses, can contaminate water bodies (e.g., lakes, rivers, coastal waters) and cause illness in people swimming or participating in other water-contact activities. EPA develops recommended water quality criteria limiting pathogens, pathogen indicators and algal toxins to protect human health in waters designated for primary contact recreation. State, territories and tribes designate waters for primary contact recreation for waters where people may swim, bathe or surf. These types of activities are likely to result in incidental ingestion of water. State, territorial, and authorized tribal governments can use these recommended criteria when setting their water quality standards or advisory notification programs.

As directed by the BEACH Act, EPA conducted studies associated with pathogens and human health and published updated criteria recommendations for pathogens and pathogen indicators based on those studies. The result is the 2012 Recreational Water Quality Criteria (RWQC) (https://www.epa.gov/sites/default/files/2015-10/documents/rwqc2012.pdf). These are national CWA section 304(a) recommended criteria designed to protect the public from exposure to harmful levels of pathogens while participating in water-contact activities, such as swimming, bathing, and surfing, in all water bodies designated for such recreational uses. These RWQC are based on bacteria (*E. coli* and enterococci) that indicate fecal contamination, and thus indirectly, the presence of fecal pathogens.

In 2018, EPA published its first five-year review of the 2012 RWQC (https://www.epa.gov/sites/default/files/2018-05/documents/2017-5year-review-rwqc.pdf) as required by BEACH Act amendments to the CWA. Based on that review, EPA did not choose to revise the 2012 national CWA Section 304(a) recommended recreational water quality criteria. High priority actions identified in the report and subsequently accomplished include the completion and publication of recreational criteria for cyanotoxins and analytical methods for coliphage, virus that infects the bacteria *E. coli* found in human waste. The development of coliphage-based RWQC are under consideration. EPA expects to complete the second five-year review of the RWQC in late 2022 (https://www.epa.gov/wqc/five-year-reviews-epas-rwqc).

EPA continues to recommend that states and authorized tribes adopt the 2012 recreational criteria to protect people participating in water-contact activities where incidental ingestion is likely.

Virginia Beach, Virginia. S. Barash

2.1 New Criteria and Tools

2.1.1 Alternative Methods Calculator Tool

States and other partners can opt to develop site-specific criteria rather than adopting EPA's 2012 national recommended RWQC. In 2021, EPA released the Alternative Methods Calculator Tool (AltCalc Tool) (https://www.epa.gov/system/files/other-files/2021-11/site-specific-alt-calculator-tool.xlsm). This is a user-friendly Excel-based tool to determine whether an alternative microbial water quality indicator and/or method can be used to derive alternative site-specific recreational water quality criteria. New methods or indicators might provide improvements over existing approaches with regards to speed, sensitivity, specificity, cost, ease of use, and performance.

The AltCalc Tool is used in conjunction with EPA's Site-Specific Alternative Recreational Criteria Technical Support Materials for Alternative Indicators and Methods (https://www.epa.gov/sites/default/files/2015-11/documents/sitespecific-alternative-recreational-indicators-methods.pdf). These outline the scientific information needed before an alternative indicator/method can be used to replace a recommended or approved method on a site-specific basis. Tool users enter water quality data from an EPA-approved method and an alternative method into the AltCalc Tool that performs a statistical comparison to determine whether the two methods produce a consistent and predictable relationship. If so, with EPA approval, the user may replace the EPA-approved water quality method with the alternative method.

Algal bloom near Gwynn Island, Virginia. Virginia Institute of Marine Science.

2.1.2 2019 Recreational Water Quality Criteria or Swimming Advisories for Cyanotoxins

Since the passage of the BEACH Act, EPA has focused its implementation on protecting public health from exposure to fecal pathogens in recreational waters. Recently, another human health concern has emerged when toxins are released by cyanobacteria in recreational waters. Cyanobacteria, commonly called blue-green algae, are naturally occurring photosynthetic bacteria found in freshwater and marine ecosystems. Under certain environmental conditions, such as elevated levels of nutrients, warmer temperatures, still water, and plentiful sunlight, cyanobacteria can rapidly multiply to form harmful algal blooms (HABs). HABs have been reported in ambient water in every state. As the cyanobacteria multiply creating cyanobacterial HABs (cyanoHABs), some of the cells can produce toxic compounds. These toxic compounds, known as cyanotoxins, can be harmful to humans, animals, and the environment. CyanoHABs (https://www.epa.gov/cyanohabs) can also harm the economy, drinking water supplies, property values, and recreational activities, including swimming and fishing.

During a cyanoHAB event, the toxin concentrations can rapidly increase and may become elevated before a visible bloom is observed. Elevated cyanotoxin concentrations in surface waters can also persist after the bloom fades, so human exposures can occur even after the visible signs of a bloom are gone. Microcystins and cylindrospermopsin are two types of cyanotoxins that can be produced by a variety of cyanobacteria species. Studies indicate that, at certain concentrations, short-term and long-term adverse effects from oral exposure of microcystins and cylindrospermopsin include liver and kidney damage.

EPA issued recommendations for recreational water quality criteria and swimming advisories for microcystins and cylindrospermopsin in 2019 (https://www.epa.gov/sites/default/files/2019-05/documents/hh-rec-criteria-habs-document-2019.pdf). These national CWA section 304(a) recommendations are designed to protect the public from exposure to harmful levels of cyanotoxins while participating in water-contact activities, such as swimming, bathing, and surfing, in all water bodies designated for such recreational use. EPA identified recommended concentrations of these cyanotoxins at or below which human health is protected while swimming or participating in other water-contact activities. The recommendations reflect the latest scientific knowledge on the potential human health effects from recreational exposure to these two cyanotoxins. The recommendations are based on children's recreational exposures because children have a higher share of incidents during HAB-associated outbreaks. Studies show that children have a greater potential exposure than adults because

they are generally in the water longer and ingest more water while in the water (DeFlorio-Barker et al. 2018; DuFour et al. 2017).

EPA's *Final Technical Support Document: Implementing the 2019 Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin* (https://www.epa.gov/system/files/documents/2021-08/final-tsd-implement-2019-rwqc.pdf.pdf) details how states, territories, and authorized tribes can adopt these recommended criteria into their water quality standards or swimming advisory programs. The document focuses on the human health risks associated with incidental ingestion while recreating in freshwaters containing these harmful cyanotoxins. EPA recognizes that there may be circumstances where cyanoHABs can impact downstream marine and estuarine waters. The document provides information on occurrence and incidental ingestion in estuarine and marine water for states, territories, and authorized tribes to consider but does not provide recommendations for those waters.

EPA has published materials to help recreational waterbody managers responsible for monitoring and responding to cyanobacterial blooms. These materials include customizable infographics (https://www.epa.gov/cyanohabs/infographics-help-educate-public-habs-basics) and a communication toolbox (https://www.epa.gov/cyanohabs/communicating-about-cyanobacterial-blooms-and-toxins-recreational-waters) with examples of public messages, press releases, and signage that recreational water body managers may use to inform the public of increased health risks associated with exposure to HABs, or cyanobacteria, and their toxins.

For the protection of human health when recreating, EPA recommends that states, territories, and authorized tribes adopt the released criteria/swimming advisory values for microcystins and cylindrospermopsin. At the same time, EPA will continue to develop and release criteria for other cyanotoxins.

Atlantic Beach, North Carolina. K. Davis

2.2 Criteria Under Development

EPA has been working for several years to develop RWQC for coliphage, a viral indicator, to ensure public health protection from water sources that have been influenced by viral fecal contamination. Increasing evidence through microbial risk assessments and epidemiological studies shows that viruses cause most of the illnesses associated with primary contact recreation in surface water impacted by human sources. The *2017 Five-Year Review of the Recreational Water Quality Criteria* (https://www.epa.gov/sites/default/files/2018-05/documents/2017-5year-review-rwqc.pdf) explains the need for coliphage criteria and describes in detail the criteria development process – literature reviews, methods refinement, coliphage experts workshop, and epidemiological data analysis.

Health studies indicate that viruses that replicate in the gastrointestinal tract (enteric viruses) cause the majority of swimming-related illnesses in waters affected by human fecal contamination (CDC 2011; Garciaa et al. 2018; Soller et al. 2010). Enteric viruses enter surface water from treated and untreated sources since traditional wastewater treatment processes are not designed to reduce enteric viral loads. Enteric viruses are difficult and slow to culture and there is a need for an indicator that can reflect the potential risks from enteric viruses in contaminated recreational waters. Viruses that infect the bacteria *E. coli* are called coliphages and are found in high levels in human sewage and therefore may be an ideal candidate as a viral indicator for the development of recreational water quality criteria. Coliphages exhibit numerous desirable indicator characteristics. For example, they are abundant in domestic wastewater, raw sewage sludge, and polluted waters; are physically similar to viruses causing illnesses associated with primary contact recreation; are nonpathogenic; are amenable to overnight culture methods and can be counted cheaply, easily, and quickly; are shown in some studies to be correlated with gastrointestinal illness among swimmers; and are similarly resistant to sewage treatment and environmental degradation as enteric viruses of concern.

In 2018, EPA published draft analytical methods for coliphage. Method 1642 was developed in response to stakeholders' needs for a validated method for coliphage for monitoring recreational waters and wastewater effluents. Method 1643 was developed to address stakeholder needs for a lab-validated coliphage method for monitoring secondary (no disinfection) wastewater matrices under the CWA. Through the National Shellfish Sanitation Program, the U.S. Food and Drug Administration requires coliphage sampling results to determine when shellfish harvesting areas can open following wastewater treatment plant emergency or extreme weather events.

2.3 New Health Studies

EPA used a pooled data set of over 80,000 beachgoers from 13 beach sites across the United States to compare risks associated with the fecal indicator bacteria *Enterococcus* for different age groups across different exposures, sites, and health endpoints (Wade et al. 2022). The 13 beach sites were categorized according to the predominant type of fecal contamination. Risk of illness associated with water quality was compared among the exposed groups and across different age categories, including children. Under many exposure scenarios, children were at higher risk of gastrointestinal illness associated with exposure to fecal contamination as measured by *Enterococcus*. The source of fecal contamination and the intensity of swimming exposure were also important factors affecting the association between *Enterococcus* species and swimming-associated illness.

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Section 3. Improvements to Methodologies and Techniques for Monitoring Coastal Recreation Waters

The BEACH Act directs EPA to provide recommendations on improvements to monitoring methodologies and techniques. For years, EPA has been developing rapid methods, microbial source tracking and predictive tools as well as improving the science and integration of monitoring and modeling pathogens in coastal recreation waters. Some of these monitoring techniques are used in participatory science efforts supported by EPA. EPA recommends that states, territories, and tribes explore using the methods and tools described in this section.

3.1 Advances in Methods

3.1.1 Rapid Methods

Culture-based laboratory methods to monitor microbial water quality require more than 18 hours to obtain results. To reduce the number of swimming-related illnesses, beach managers need quicker ways to determine when beaches are unsafe for swimming. The 2012 national CWA section 304(a) recommended recreational criteria include a rapid quantitative molecular based method for *Enterococcus*, a fecal indicator bacteria used to measure the total level of fecal pollution in a water sample. This method relies on the quantitative polymerase chain reaction (qPCR) technology, which measures the concentration of *Enterococcus* DNA. This method produces results in less than four hours, giving beach managers the ability to alert beach-goers to unsafe levels of microbial contamination on the same day that the sample is taken. Earlier notification of health hazards at beaches could result in a potential reduction in the number of swimming-related illnesses due to exposure to waterborne pathogens. EPA has continued to update and refine these methods; see EPA Method 1609.1 (https://www.epa.gov/sites/default/files/2015-08/documents/method_1609-1-enterococcus-iac_2015_3.pdf) and Method 1611.1 (https://www.epa.gov/sites/default/files/2015-08/documents/method_1611-1-enterococcus_2015.pdf).

EPA researchers have also further refined Draft Method C, a standardized qPCR method for quantifying *E. coli* concentrations in recreational fresh waters. Method C can provide same-day results for improving public health protection with demonstrated sensitivity, specificity, and data acceptance criteria. EPA and Michigan tested the use of Method C for three years in a jointly conducted large-scale data collection effort to compare the occurrence of culturable *E. coli* and *E. coli* determined by the qPCR method, at more than 100 recreational beach sites in Michigan. The study indicated a correlation between results of the two *E. coli* monitoring methods for each of the multi-site datasets, suggesting that these methods may provide the same beach notification outcomes more than 90% of the time.

Droplet digital PCR (ddPCR) is a newer PCR-based technology and has promise for use as a rapid method for recreational waters due to increased sensitivity detecting target DNA. EPA completed a single laboratory validation of a ddPCR method for *E. coli* and enterococci based on a method used in a recent pilot project in San Diego, California.

In response to the need for microbial source tracking methods to characterize human fecal pollution sources in recreational waters, EPA conducted a national multiple laboratory validation study resulting in standardized EPA Methods 1696.1 and 1697.1 for the characterization of human sources of fecal pollution in ambient marine and fresh waters (see Section 3.2 Microbial Source Tracking for more information). EPA anticipates that stakeholders will use these methods to identify trends in human fecal contamination, to provide additional information to support water quality management decisions, and to help determine actionable outcomes that can improve public health protection of fresh and marine recreational waters. These updated implementation tools are available to the public at https://www.epa.gov/cwa-methods/other-clean-water-act-test-methods-microbiological.

A standard control material developed in collaboration with the National Institute of Standards and Technology will also be available to the public (Willis et al. 2022).

Washington state Beach Environmental Assessment Communication and Health Program sign.

3.1.2 Coliphage Methods

In 2018, EPA published two draft analytical methods for coliphage. Method 1642 was developed in response to stakeholders' needs for a lab-validated method for coliphage for monitoring recreational waters and wastewater effluents. Method 1643 was developed to address stakeholder needs for a lab-validated coliphage method for monitoring secondary (no disinfection) wastewater matrices under the CWA. See Section 2 of this report for additional information on coliphage.

3.2 Microbial Source Tracking

Fecal pollution can originate from numerous sources such as humans, domestic and agricultural animals, and wildlife, making it challenging for local water quality managers to pinpoint the source and prevent future contamination events. EPA's Office of Research and Development maintains an active research program to develop, validate, and implement tools to characterize fecal pollution sources in environmental waters. General fecal indicators (enterococci and *E. coli*) typically used to assess fecal pollution do not provide information on the sources of fecal contaminants. The level of human health risk can change from one animal source to another, and water quality managers will likely use different remediation strategies based on the source of fecal pollution.

EPA researchers have developed several tools to characterize the sources of fecal microbial contamination. Among these microbial source tracking tools are host-associated qPCR methods, which can quantify fecal pollution levels and identify a fecal pollution source. In 2019, EPA published Method 1696 and Method 1697, the first nationally lab-validated protocols for human fecal pollution source characterization in recreational waters. These methods were recently updated (Method 1696.1 and Method 1697.1) as mentioned in the Section 3.1 Advances in Methods. Continued research activities include (1) the development of human and other fecal source-associated methods and the science to support implementation in recreational water settings and (2) microbial source tracking case studies to evaluate performance in real-world scenarios.

In a recent study, EPA used host-associated qPCR methods to identify microbial contamination from key animal groups potentially contaminating recreational waters at three Great Lake beach areas (Li et al. 2021). Water samples were analyzed for human, ruminant (e.g., cattle, deer), avian and canine fecal

pollution sources. The results of these analyses identified fecal source pollution trends and provided information on method performance at Great Lakes recreational beaches.

Measuring water temperature in Washington. Washington State Department of Ecology.

3.3 Sanitary Survey App for Marine and Fresh Waters

Sanitary surveys are one of the most widely accepted tools to assess potential sources of pollution that can adversely affect public health. A sanitary survey is a method of investigating the sources of fecal contamination to a waterbody by collecting information at the beach, shoreline, and surrounding watershed. Information collected may include weather conditions, number of people, location and condition of bathrooms, presence of algae, land use information, stormwater outfall locations, and surface water quality. The data can be used to identify sources and magnitude of a water quality problem, make decisions on beach closures and remediation actions, and implement predictive tools to ensure same day swimming advisory decisions. Jurisdictions can reduce or eliminate beach advisories and closures by identifying and mitigating pollution sources. These efforts can ultimately promote safe public access to urban waterways and lead to aquatic ecosystem restoration.

In July 2020, EPA released its updated Sanitary Survey App for Marine and Fresh Waters with enhanced features to help states, territories, and tribes gather sanitary survey data to identify sources of fecal contamination and potential HAB events affecting coastal recreation waters. In 2021, EPA was able to allow increased access to the Sanitary Survey App for use by local governments, participatory scientists, non-governmental organizations, and the public. The Sanitary Survey App consists of four surveys — routine surveys for marine and freshwater environments for conducting short-term assessments and annual surveys for marine and freshwater environments for conducting long-term assessments. The surveys allow users to collect and share data on potential sources of fecal pollution and information on potential HAB events in local surface waters, including designated recreational waters. The data from the App can be exported for use in predictive models and for sharing within or between groups.

The Sanitary Survey App can be used on any device (i.e., phone, tablet, computer) and special features include photo storage, real time geolocation, links to websites such as the National Weather Service to access data, and free data storage. As of April 2022, the App has 332 users and 745 surveys have been conducted. Additional information is located on the Sanitary Surveys for Recreational Waters webpage (https://www.epa.gov/beach-tech/sanitary-surveys-recreational-waters). EPA is currently developing a Quality Assurance Program Plan (QAPP) template for the Sanitary Survey App to streamline future QAPP development for participatory science groups and non-governmental organizations. A QAPP must be completed to use the EPA Sanitary Survey App.

3.4 Modeling

3.4.1 Virtual Beach

Virtual Beach is a software package designed for developing site-specific statistical models for the prediction of pathogen indicator levels at recreational beaches. As a follow up to earlier versions of Virtual Beach that focused on *Enterococcus* and *E. coli* indicators that can be used in fresh or marine waters, EPA's recent recreational water predictive modeling efforts have focused on developing statistical models for predicting coliphage and qPCR-based molecular data at multiple Great Lake recreational beaches. In the last year, software development efforts have concentrated on creating a web-based version of Virtual Beach (Web-VB), with focus on cross-validation for a more accurate assessment of the predictive potential of developed models. Web-VB will depend heavily on machine learning techniques, and include ensemble modeling, so that predictions can be made using a weighted average of predictions from multiple modeling techniques. It will be used to analyze water quality data (traditional fecal indicator bacteria, cultured coliphage, and qPCR-based molecular data) from several marine beach sites in the Gulf of Mexico collected in the spring and summer of 2022.

EPA is also exploring ways to integrate data from the Sanitary Survey App (see Section 3.3) into Web-VB to help streamline the development of site-specific predictive models.

3.4.2 Quantitative Microbial Risk Assessment

Quantitative Microbial Risk Assessment (QMRA) is a tool that can be used to estimate the human health risks associated with exposure to fecal pathogens in recreational water. QMRA can be used to support evaluation of candidate fecal indicators and pathogen surrogates, thus providing additional tools to help manage recreational waters and protect public health. QMRA can also help evaluate the relative risks between different sources of fecal contamination. EPA is revising technical support materials for developing site-specific water quality criteria accounting for non-human fecal sources using QMRA. States, territories, and authorized tribes can use these tools along with EPA's Sanitary Survey App (https://www.epa.gov/beach-tech/sanitary-surveys-recreational-waters), which also supports QMRA.

3.5 Participatory Science

Participatory science offers new opportunities for the public and EPA to interact to improve environmental science and protection. Participatory science engages the public to formulate research questions, collect data, and interpret results. The focus may be on a specific area where information is used to encourage social learning, empower local groups, and aid communities with potential environmental justice concerns to bring information to decision makers and regulators. It is a transformational approach to environmental protection that engages volunteers, allowing large numbers of people to contribute to science. EPA supports these initiatives through a range of resources including funding, technical support, and tools. In 2021, EPA published a StoryMap on participatory science (https://storymaps.arcgis.com/stories/57b2ee78221341a18b0f7ebe8017340d) with interactive maps highlighting the importance of participatory science and how EPA supports these efforts. Featured projects include the Chesapeake Monitoring Cooperative that trains participatory scientists in collecting water quality data and the Hui O ka Wai Ola project that enlists volunteers to collect water quality data at more than 30 beach-access sites in Hawaii. Water quality focused projects, including several related to bacterial monitoring, are also highlighted on EPA's Community and Citizen Science website (https://www.epa.gov/citizen-science/community-citizen-science-water-projects).

Hui O ka Wai Ola project in Maui, Hawaii.

The EPA Sanitary Survey App for Marine and Fresh Waters allows the public to report on conditions of local water bodies such as the occurrence of algae, surface water quality, and location of storm water outfalls. This helps waterbody managers monitor and assess the condition of recreational waters.

The Cyanobacteria Monitoring Collaborative (https://cyanos.org/) maintains three tools for participatory scientists to get involved with cyanobacteria monitoring. The BloomWatch App is a crowdsourcing tool for reporting cyanobacteria blooms. The CyanoScope is a tool for collecting cyanobacteria, preparing microscope slides, identifying cyanobacteria in the sample, uploading images and locations to iNaturalist.org, and engaging the iNaturalist community to confirm the identity. Monitoring cyanobacteria populations over time to track seasonal patterns is done by participatory scientists and professionals through the CyanoMonitoring tool.

In order to support collection of actionable data by participatory scientists, in 2019 EPA prepared a Handbook for Citizen Science Quality Assurance and Documentation (https://www.epa.gov/citizen-science/quality-assurance-handbook-and-guidance-documents-citizen-science-projects) to help external organizations understand how to prepare a Quality Assurance Project Plan (QAPP). The Handbook provides an overview about preparing different levels of quality planning based on the kind of data to be collected. As indicated in the Sanitary Survey App section, EPA is developing a QAPP template for the Sanitary Survey App to streamline the process for participatory science groups and non-governmental organizations to complete this requirement.

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Section 4. Evaluation of Federal, State, Territorial, Tribal and Local Efforts to Implement the BEACH Act

Federal, state, territorial, tribal, and local governments work cooperatively to implement the BEACH Act with the shared goal of conducting and improving beach monitoring and public notification efforts for coastal recreation waters to reduce risks to human health. The following section summarizes program highlights and innovations that federal, state, territorial, tribal, and local governments have been implementing since the 2018 BEACH Act Report to Congress.

4.1 EPA Efforts

EPA has made significant progress in strengthening protection of public health at our nation's beaches by administering BEACH Act grants, developing user-friendly tools to report beach monitoring and notification data, researching innovative and rapid monitoring and predictive methods for more timely beach decisions, and facilitating knowledge sharing with water quality managers, stakeholders, researchers and public health officials across federal, state, territorial, tribal, and local levels. Some of the major EPA accomplishments over the past four years follow in this section.

4.1.1 EPA BEACH Act Grants

EPA awards grants under authority of the BEACH Act to eligible states, territories, and tribes with beaches in marine and estuarine waters and on the Great Lakes to develop and implement programs to monitor their beaches and notify the public when it is not safe to swim. During each swimming season, state, tribal, territorial, and local health and environmental protection agencies monitor the quality of water at coastal recreation beaches that they have prioritized. When levels of fecal pathogens or pathogen indicators in the water are present at levels associated with harm to human health, these agencies notify the public by posting beach warnings or closing the beach. These grants help local authorities monitor beach water quality and notify the public of conditions that may be unsafe for swimming.

Three factors influence the grant allocations: (1) the length of the beach season, (2) the number of miles of shoreline, and (3) the populations of coastal counties. EPA's formula for calculating grant allocations is published in the Federal Register (75 FR 1373; January 11, 2010).

EPA has allocated more than $205 million in grants for the beach monitoring and notification programs since it started awarding grants in 2001. There are currently 30 states, five territories, and four tribes that are eligible to apply for beach grant funds. Total funding amounts for the five most recent fiscal years are shown below:

Fiscal Year	Grant Total
2022	$10,119,000
2021	$ 9,619,000
2020	$ 9,238,000
2019	$ 9,238,000
2018	$ 9,331,000

For a breakdown of how the grants were allocated among states, territories, and tribes refer to:

- Beach Grants from Fiscal Year 2001 through 2022: https://www.epa.gov/system/files/documents/2022-05/beach-grants-2022.pdf

For the required performance criteria, refer to:

- National Beach Guidance and Required Performance Criteria for Grants: https://www.epa.gov/beach-tech/national-beach-guidance-and-required-performance-criteria-grants


Wisconsin. T. Seilheimer

4.1.2 EPA Efforts to Streamline Reporting and Data Repositories for Transparency and Ease of Use

Release of Dynamic National Report Generator and other beach data tools

EPA updated and enhanced its online tools, including the Beaches Advisory and Closure Online Notification (BEACON) system, to provide up-to-date and tailored information to the public. One tool, the Dynamic National Report Generator (https://ofmpub.epa.gov/apex/beacon2/f?p=BEACON2:DNR:0:), produces annual summaries and 5-year national trend data and graphs for any year since 2014 using the most recent data, which may have been updated after EPA published an annual report. Other tools include customized reports and trend graphs that show similar information at the state and local level (https://watersgeo.epa.gov/BEACON2/reports.html).

Release of Annual Beach Swimming Season Reports

Using the data in the BEACON system, EPA releases annual reports that contain national summary statistics of beach closings and advisories that states, territories, and tribes issued during the swimming season as well as beach data trends over several years. In 2019, EPA resumed creating these reports, which had been discontinued after the 2012 swimming season. The report on the 2020 swimming season included information on how COVID-19 impacted monitoring and use of the nation's coastal and Great Lakes beaches. Swimming season results for 2021 are summarized in section 4.2.1 of this report. Beach swimming season reports released in the last four years can be found at https://www.epa.gov/beach-tech/annual-beach-swimming-season-reports.

Release of Sanitary Survey App for Marine and Fresh Waters

In July 2020, EPA released its Sanitary Survey App for Marine and Fresh Waters to help states and tribes gather sanitary survey data to identify sources of fecal contamination and potential HAB events affecting

coastal recreation waters and the Great Lakes. Section 3.3 contains additional details and more information is available at https://www.epa.gov/beach-tech/sanitary-surveys-recreational-waters.

Update to National List of Beaches
As required by the BEACH Act, EPA publishes a list of coastal recreation waters adjacent to beaches (or similar points of access) used by the public in the U.S. The list is dynamically generated online via BEACON from data provided electronically by states, territories, and tribes. The list identifies waters that are subject to a jurisdiction's beach water quality monitoring and public notification program consistent with the *National Beach Guidance and Required Performance Criteria for BEACH Act Grants*. The list also specifies beaches for which there is no monitoring or notification program. More information on the National List of Beaches can be found at https://www.epa.gov/beach-tech/national-list-beaches.

In the National List of Beaches, EPA recently added a column, "Tier 4 (B)", displaying counts for Tier 4 beaches. Tier 4 beaches are BEACH Act beach waters that are not included in a state or tribe's monitoring or notification program, including those beach waters for which fiscal constraints prevent consistency with the performance criteria. Note that not all jurisdictions utilize this additional reporting tier. See Section 4.2.1 for description of additional tiering designations.

Enhancement of Verification Tool - Monitoring Module
EPA continued to enhance the Verification Tool, which allows jurisdictions to have password-protected access so they can update and verify their data in BEACON. The most recent update of the Verification Tool was added in 2021, which enabled easier updates to water quality monitoring data.

Citation of BEACON by World Health Organization
In an article published by World Health Organization in 2021 on its updated Guidelines for Recreational Water Quality, EPA's BEACON data system is cited as the U.S. source for beach water quality information posted online. The article can be found at https://www.who.int/news/item/13-07-2021-who-launches-guidelines-for-recreational-water-quality-as-summer-heats-up.

4.1.3 EPA Working Toward More Timely Beach Decisions
See Section 3 for a description of EPA's advances in rapid methods, microbial source tracking, and predictive modeling. These tools help managers make more timely beach decisions and protect human health.

4.1.4 EPA Study on Environmental Justice and Beach Access
EPA conducted a study (Twichell et al., 2022) examining disparities in coastal access in Rhode Island by assessing 1) different populations' relative travel distances to all public coastal access and to public marine swimming beaches across the state of Rhode Island by race, ethnicity, and socioeconomics; and 2) relative travel distances to high quality public coastal amenities with no history of water quality impairment. The analysis revealed statewide disparities in access to Rhode Island's public coastal amenities, with disproportionately shorter travel distances for non-Latinx white populations, and disproportionately longer travel distances for Black and Latinx populations, in particular to public coastal sites with better water quality and to public swimming beaches. These findings have environmental justice and economic implications, as disparities in travel distances suggest that White populations experience a cost savings per coastal recreation trip, while Black and Latinx populations experience an added cost of several dollars (USD) on each coastal trip.

4.1.5 EPA Communications and Knowledge Sharing
National Recreational Water Quality Workshop
In April 2021, EPA hosted a virtual three-day National Recreational Water Quality Workshop which served as a forum for approximately 800 recreational water quality managers, stakeholders, researchers and public health officials at all levels to share information and ideas about implementing a successful recreational water program. The workshop focused on two common challenges in ambient recreational waters: fecal contamination and HABs. The workshop included pre-recorded presentations, panel discussions and poster sessions on topics including risks to recreation, restoring waters to recreational

use, advances in monitoring approaches and technology, notification and risk communication, building partnerships in recreational water monitoring and remediation, and emerging concerns. More information on the National Recreational Water Quality Workshop can be found at: https://ctic.org/2020_Rec_Workshop.

4.1.6 Additional EPA Programs Supporting the BEACH Act

National Estuary Program

Established by Congress under CWA Section 320, the National Estuary Program (NEP) is a non-regulatory EPA place-based program to protect and restore the water quality and ecological integrity of 28 estuaries of national significance, located along the Atlantic, Gulf, and Pacific coasts and in Puerto Rico. Each NEP focuses on a study area that includes the estuary and surrounding watershed. More information on the NEP is available at https://www.epa.gov/nep.

While many NEPs conduct pathogen monitoring efforts, three examples of successful pathogen monitoring programs in NEP programs – which do not span the whole range of activities in these NEPs and may represent different levels of involvement in pathogen monitoring – include Puget Sound, Washington, Casco Bay, Maine, and New York-New Jersey Harbor & Estuary Program (HEP).

- Puget Sound NEP's Shellfish Strategic Initiative has been instrumental in supporting Pollution Identification and Correction (PIC) programs in all 12 Puget Sound counties. PIC programs are an important tool for local partners to protect and restore shellfish beds and protect people from water-borne pathogens. PIC programs survey watersheds and offer education, technical, and financial assistance to help community members manage septic systems, farm animal manure, pet waste, urban wildlife, and boater/recreationalist waste to prevent pollution to waterways. Furthermore, EPA Region 10's Manchester Environmental Laboratory provides important scientific support for PIC programs through microbial source tracking, using DNA analytical methods to help evaluate whether fecal bacteria are more likely from dogs, humans, cattle, or other animals.
- Casco Bay Estuary Partnership helps report and synthesize data from two regulatory programs in the Casco Bay "State of the Bay" reports and at network monitoring meetings, to track how actions implemented in their Comprehensive Conservation and Management Plan result in changes to environmental or public health. The first regulatory program is Maine Healthy Beaches Program, which works with volunteers and staff in state parks and towns to collect samples from public beaches to be analyzed for fecal indicator bacteria. The other regulatory program is the Maine Department of Marine Resources Shellfish Program which tracks bacteria in shellfish harvesting areas to assess risks to human health.
- New York-New Jersey HEP works with 33 stakeholder groups to collect data through 36 pathogen monitoring programs. These programs monitor fecal coliform bacteria and/or *Enterococcus* and work towards identifying pollution sources, monitoring gaps, and identifying opportunities to use microbial source tracking. HEP informs and engages the public by synthesizing data from two harbor-wide programs as well as citizen science data. Their "State of the Estuary" reports help track how actions implemented in HEP's Comprehensive Conservation and Management Plan result in changes to ecological health.

Trash Free Waters Program

The BEACH Act also directs EPA to provide technical assistance to state, territorial, tribal, and local governments for the development of assessment and monitoring procedures for floatable materials. These are defined as any foreign matter that may float or remain suspended in the water column, including debris such as plastic, aluminum cans, wood products, bottles and paper products. Although it does not directly operate under the Beach Program, EPA's Trash Free Waters program works to reduce and prevent trash from entering U.S. waters and the ocean, playing a unique role in helping states, municipalities, businesses, non-governmental organizations, and concerned citizens work together to explore more effective ways to reduce the amount of litter and packaging waste that enters the water. More information on Trash Free Waters is available at https://www.epa.gov/trash-free-waters.

4.2 State, Tribal, Territorial, and Local Efforts to Implement the BEACH Act

States, territories, and tribes primarily implement the BEACH Act and ensure that public health is protected at beaches through their monitoring and notification programs. Currently, 30 states, five territories and four tribes are funded by BEACH Act grants. These programs are improved over time with the development and implementation of more innovative monitoring and notification methods. The following section focuses on state, territorial and tribal monitoring and reporting data, how beach programs address disadvantaged communities, and highlights of beach program accomplishments for jurisdictions within each EPA region.

4.2.1 Monitoring and Notification Reporting Data

This section includes highlights from the *EPA's Beach Report: 2021 Swimming Season*. States, territories, and tribes with coastal and Great Lakes beaches submitted information to EPA about beach water quality monitoring and notification actions (i.e., beach closings and advisories) for the 2021 swimming season, covering the period of January 1 through December 31. The report includes data submitted to EPA as of June 10, 2022.

"Program beaches" have, at minimum, a program to notify the public if swimming in the coastal recreation water is unsafe, and most also have a program to routinely monitor the water quality. Monitoring frequency of beaches is determined using a three-tier classification of beaches based on the amount of historical illness risk from swimming at a beach, frequency of beach use, or both. EPA recommends that samples be taken one or more times per week during the swimming season at Tier 1 (highest priority beaches because of high risk and/or high use) beaches and once per week at Tier 2 (beaches with high or moderate use and moderate or low risk) beaches, starting a month before the swimming season, to monitor whether fecal indicator bacteria (e.g., enterococci) exceed the levels derived from the water quality standards that apply to that water. For Tier 3 (beaches with low use and low or very low risk) beaches, EPA recommends a minimum sampling frequency consistent with other ambient water quality sampling programs. However, Tier 3 beaches should be reviewed periodically to determine whether they should be reclassified as Tier 1 or Tier 2 or non-program beaches. Jurisdictions have the discretion to follow EPA's recommended tiering definitions or may utilize a different tiering approach.

In 2021, 68% of coastal and Great Lakes program beaches in the United States were monitored for pathogens or pathogen indicators. Figure 1 shows the number of beaches that were monitored and number of program beaches in each state, territory, and tribe in 2021. When monitoring results show exceedances for pathogens or pathogen indicators, states, territories, and tribes either issue a beach advisory that warns people of possible risks of swimming or a beach closing that closes the beach to public swimming. The states and local agencies that do not routinely monitor water quality use models or policies (e.g., advisory after a certain amount of rainfall) as a basis for issuing notification actions at beaches. Advisories or closures typically stay in effect until monitoring shows that levels of pathogens or pathogen indicators comply with the beach notification value derived from the applicable water quality standards.

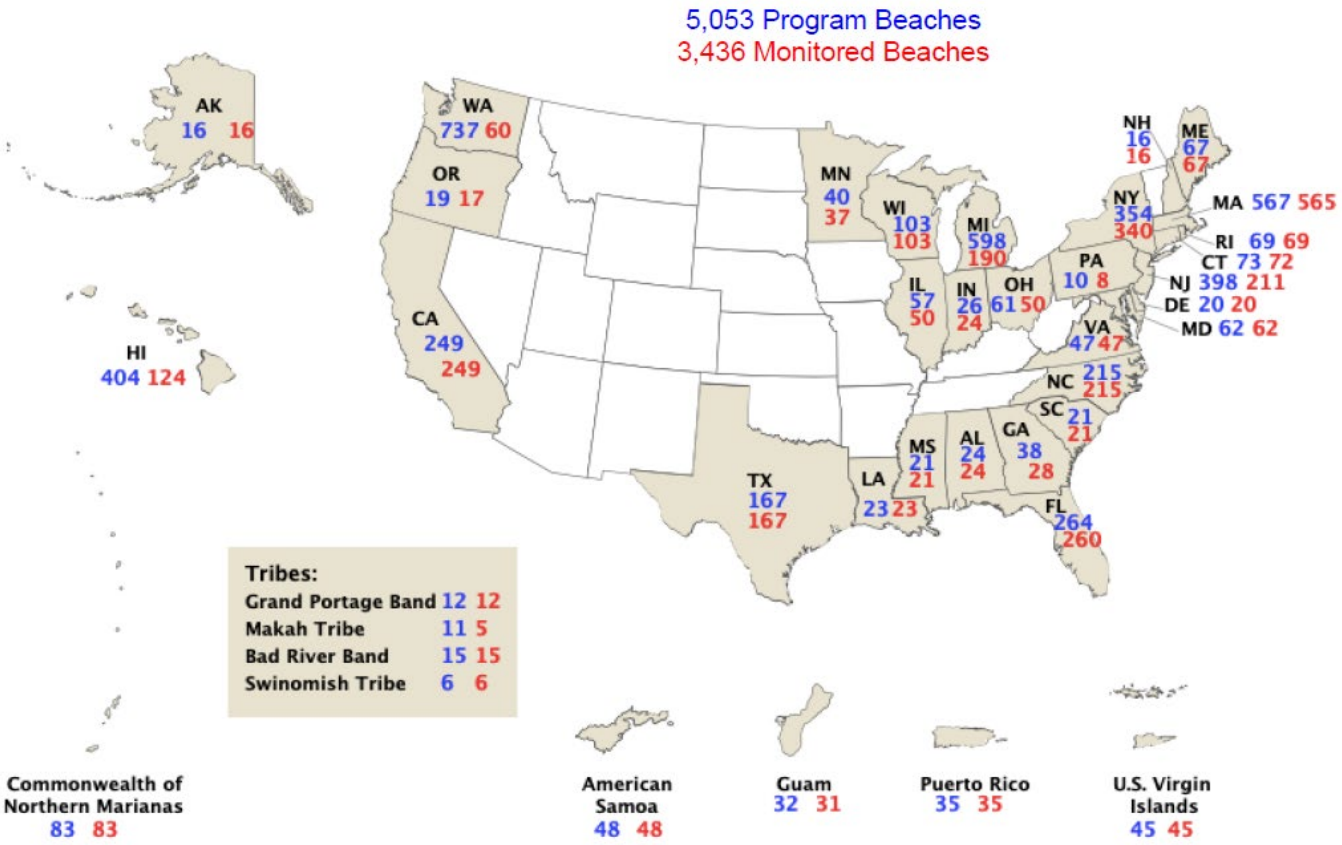

Figure 1. Number of total and monitored coastal and Great Lake program beaches by state/territory/tribe

In 2021, 33% of the nation's program beaches (1,644 out of 5,035) had at least one advisory or closing. Figure 2 shows the percent of program beaches with one or more advisories or closings in years 2018 through 2021.

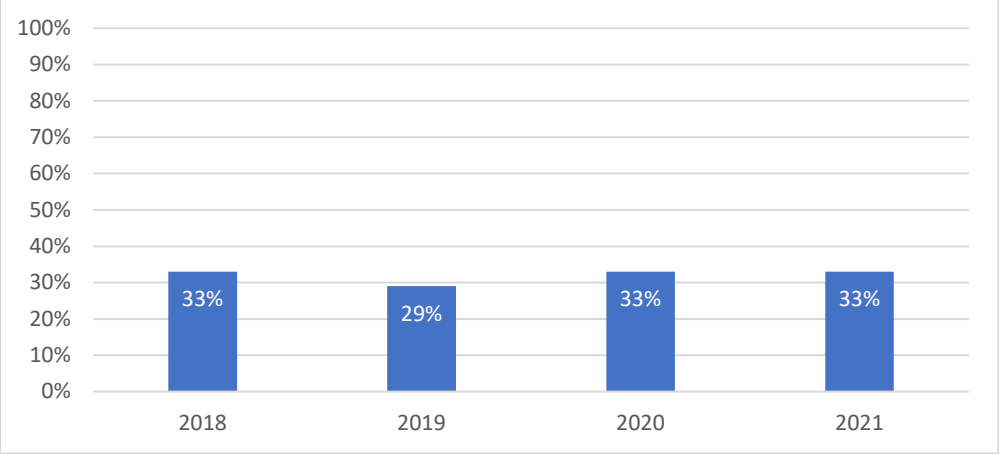

Figure 2. Percent of nation's program beaches with one or more notification actions

Beach advisories and closings can result from a variety of pollution sources: stormwater runoff after rainfall; pet and wildlife waste; waste from boats; leaking septic systems; malfunctions at wastewater treatment plants or broken sewer lines; overflows from sewer systems; or HABs. To help minimize the risk to beachgoers, EPA is, for example, helping communities improve sewage treatment plants and reduce adverse impacts from rainfall as much as possible by providing water infrastructure investment loans.

States, territories, and tribes reported the possible sources of pollution shown in Figure 3 that resulted in beach advisories or closings or were identified in beach surveys at program beaches in 2021.

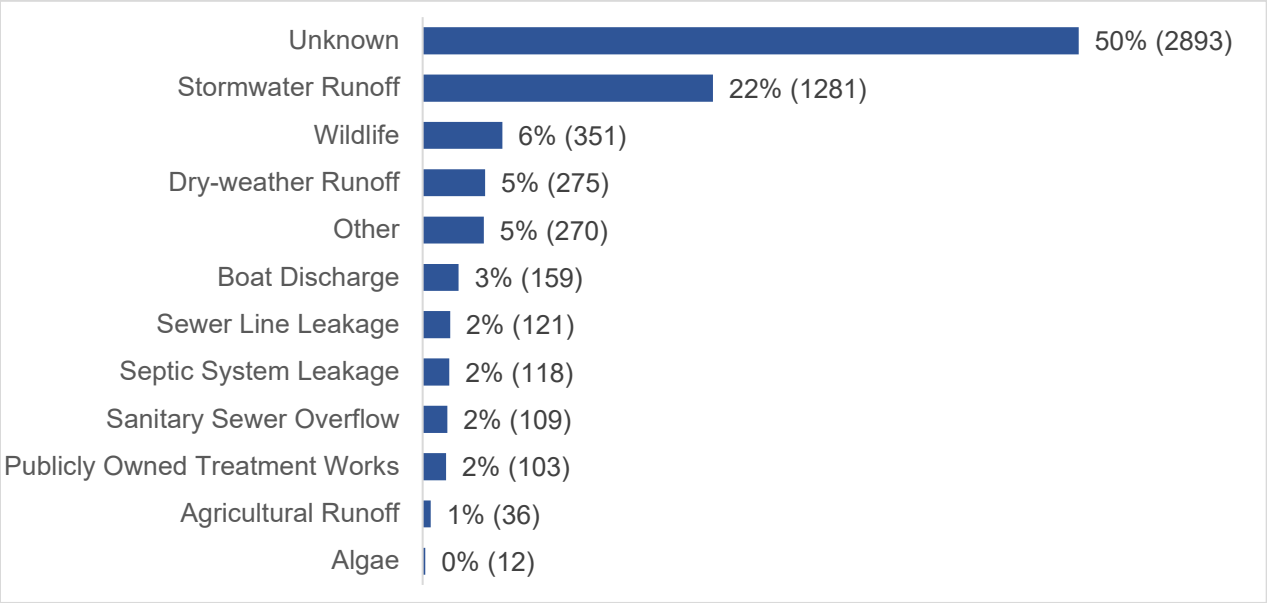

Figure 3. Reported possible sources of pollution in 2021

States, territories, and tribes issued 9,382 beach notification actions (i.e., advisories or closings) during the 2021 swimming season. An advisory or closing is typically removed when follow-up water quality monitoring shows that pathogens or pathogen indicators comply with applicable beach notification values derived from applicable water quality standards. For 82% of the notification actions in 2021, coastal recreational waters no longer exceeded applicable beach notification values and beaches were deemed safe for swimming within a week (Figure 4). In 2021, 17% of the notification actions lasted only one day, and 22% ended between one and two days.

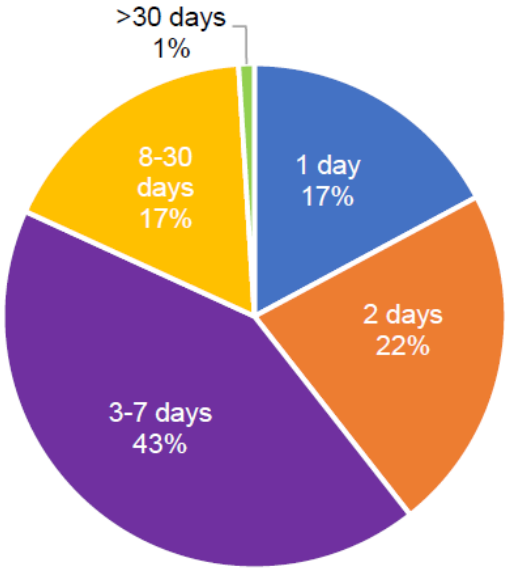

Figure 4. Duration of beach notification actions in 2021

Program beaches on U.S. coasts and along the Great Lakes were open and safe for swimming 92% of the time in 2021. EPA calculates the total available beach days and the number of beach days with advisories or closings to better track trends over time. To calculate total available beach days, EPA adds the length of the beach season (in days) for every program beach in each state, territory, and tribe. For 2021, EPA

determined that 723,783 beach days were associated with the swimming seasons of 5,053 beaches with monitoring and/or notification programs. Notification actions were reported on 54,578 days out of those 723,783 beach days. Figure 5 shows the percentage of beach days that the nation's program beaches were open and without any advisories in years 2018 through 2021.

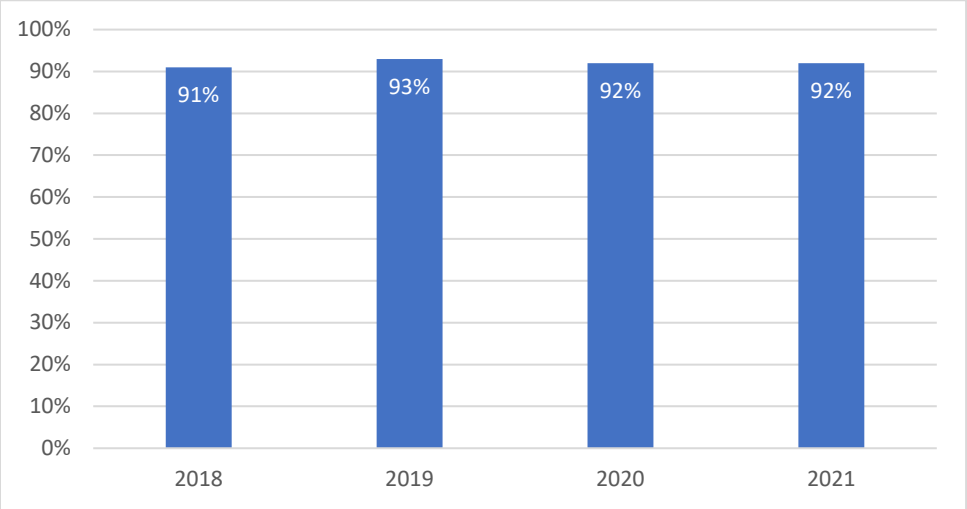

Figure 5. Percent of days the nation's program beaches were open and safe for swimming

4.2.2 Environmental Justice Preliminary Analysis

EPA is exploring approaches to quantify how many beaches in the program serve disadvantaged communities, and how different aspects of the program benefit those communities. EPA conducted a preliminary analysis using data from two major sources: the BEACON system, which has monitoring or notification action information about beaches in the program, and EPA's EJScreen. EJScreen is an environmental justice (EJ) mapping and screening tool with information on different environmental and social indicators at the Census Block Group level. These indicators can help identify which communities may be of interest when addressing environmental justice concerns. In EPA's initial effort to determine if a beach serves a disadvantaged community, EPA quantified EJScreen data for communities within five miles of a beach. If at least 25% of the communities within the five miles of a beach had three or more EJScreen indicators at or above the 80th percentile, those beaches were identified as beaches that serve disadvantaged communities. As EPA obtains important feedback from the BEACH Act jurisdictions and the public, the Agency will continue to refine the selection methods for determining disadvantaged communities.

The preliminary analysis indicates several noteworthy statistics demonstrating that disadvantaged communities are benefiting from BEACH Act funding. Of the U.S. coastal recreation beaches identified as beaches that serve disadvantaged communities, the vast majority (81.2%) are program beaches. This means that the majority of beaches serving disadvantaged communities have a notification program in place and are eligible for BEACH Act grant funds. Additionally, nearly 40% of beaches in disadvantaged communities are being prioritized for grant funds (i.e., they are Tier 1 beaches) because they have been identified as beaches of high use, high risk, or both. Beach actions include advisories and closures and can result from monitoring data or from policy-based decisions. To quantify these beach actions, we used data on the number of beaches with an action, the total number of beach actions, and the duration (number of days) of the beach action. In 2020, there were 1,688 total beaches with actions; of these, nearly 40% of events occurred at beaches serving disadvantaged communities. These beaches are likely prioritized for monitoring because they have variable water quality, but the EJScreen analysis demonstrates that disadvantaged communities are benefiting from the prioritization and actions taken.

4.2.3 Innovative or Effective Approaches

This section highlights innovative or effective examples of beach programs or research from states, tribes, territories, and localities that are recipients of BEACH Act grants (also referred to as jurisdictions). While not all of the highlights mentioned here are funded by BEACH Act grants, they provide examples of new methods or activities that can inform or support more innovative beach monitoring and notification programs. The information is presented by geographic region based on EPA's Regional offices.

New England (EPA Region 1) beach grant jurisdictions have focused on developing innovative microbial source tracking methods to monitor sources of fecal contamination in coastal waters. Notably, Maine has been tracking human fecal contamination sources using optical brighteners. They are also developing DNA markers in collaboration with the University of New Hampshire for microbial source tracking of human and non-human sources of fecal contamination. Rhode Island has been exploring cutting-edge monitoring and predictive modeling methods. Rhode Island utilized Virtual Beach, a statistical modeling software package developed and supported by EPA, to evaluate factors influencing *Enterococcus* concentration in beaches with persistent water quality problems in Narragansett Bay and found that the best predictors of water quality were unique to each beach. Furthermore, Rhode Island has been investigating a novel testing technology called TECTA™ that may serve as an alternative to traditional *Enterococcus* analysis methods with shorter turnaround time for test results due to built-in automated elements. In 2018, Rhode Island also completed a qPCR study to build capacity in state laboratories for rapid testing in beach water samples and succeeded in establishing qPCR capabilities in state laboratories to target pathogenic strains of Vibrio and various microbial source tracking functions. Lastly, Rhode Island has undertaken studies focused on inequities in beach water quality and access. In 2018, Rhode Island Department of Health completed a study to statistically examine water quality trends in four areas of Narragansett Bay to determine if these locations would be suitable for primary contact recreation as part of the Urban Beach Initiative, an ongoing effort to create clean and safe recreational outlets for at-risk communities.

In **EPA Region 2**, New York City provides an example of implementing a successful public notification and risk communication program using several forms of communication and languages. They notify the public of beach water quality status changes using on-site beach signs, websites, a 311 government service hotline, an information sharing system for subscribers ("Notify NYC"; notifications via Twitter, RSS feed, email and SMS), a free texting service ("Know Before You Go"), and press releases. The "Know Before You Go" texting service allows subscribers to view beach closures and warnings at public beaches before going to a public beach. This service has been successful and had roughly 15,000 English language subscribers and 615 Spanish language subscribers in 2021. Additionally, New York and New Jersey utilize innovative monitoring methods. In 2019, New York City launched a pilot project to assess the use of rapid methods to inform same-day decision making using qPCR sampling and analysis. New Jersey utilizes sanitary surveys to identify possible pollution sources and determine whether beaches should be closed for recreational uses when exceedances of *Enterococcus* occur during sampling. Lastly, Puerto Rico upgraded the implementation of their comprehensive evaluation to measure notification effectiveness by successfully digitalizing the evaluation survey.

Sandy Point State Park, Maryland. C. Thomson

In the **Mid-Atlantic** (EPA Region 3), Maryland has used sanitary surveys in shellfish waters and beaches, working with local health departments to address sources of fecal contamination, especially high-risk sources of human pathogens. Delaware developed GIS field map surveys to conduct surveys on pollution sources in recreation waters by capturing bather loads and other site parameters. Additionally, Delaware has begun using EPA environmental justice tools such as EJScreen in addition to GIS mapping methods, to identify higher bather loads in areas that were not historically monitored. If these unmonitored areas include underserved communities, the state is looking for ways to add these areas into the monitoring program. Finally, the local government of Erie County, Pennsylvania is working with a regional science consortium to collect additional samples (separate from regulatory samples) to develop predictive models which assist beach managers in making decisions on beach closures.

In the **Southeast** (EPA Region 4), South Carolina recently worked with local municipalities and counties to create an online public notification and communication system called Check My Beach (www.checkmybeach.com). This website links to South Carolina Department of Health and Environmental Control's beach monitoring webpage and aims to target beachgoers who are using mobile phones to check beach safety updates. In 2019-2020, they partnered with local governments and organizations to publicize Check My Beach via beach signs (with QR codes for mobile phones), flyers, websites and social media, and conducted a pilot study to assess usage and web traffic data. They found that Check My Beach was used by over 16,000 unique visitors, of which 77% were mobile phone users and 47% proceeded to the beach monitoring webpage after using Check My Beach, resulting in increased visitation to web pages with important beach safety information. Additionally, they found overwhelmingly positive results in a user survey assessing user satisfaction of Check My Beach. These results indicate that Check My Beach is serving as a successful beach advisory and notification system that is reaching the target audience – mobile phone users who may be beach goers. While Check My Beach was initially launched for South Carolina's northern coast, it will be expanded to include the entire state. Georgia employs bilingual beach advisory signs in English and Spanish and works on a series of notification and public engagement efforts. These efforts include distributing a flyer with frequently asked questions to the public at health fairs and festivals, giving presentations to local organizations and schools about the beach sampling and notification systems, and holding an annual coastal environment festival called CoastFest. CoastFest draws thousands of visitors and has an educational booth about the beach water monitoring and notification program.

Lake Superior, Wisconsin. M. Knapstein

In the **Midwest** (EPA Region 5), several jurisdictions have adopted rapid qPCR methods. Michigan worked in collaboration with EPA's Office of Research and Development (ORD) and partner laboratories in the state to conduct studies at select beaches to compare EPA draft Method C, a rapid qPCR method developed by EPA ORD for quantitative detection of *E. coli*, with current culture-based methods. With help of ORD statisticians, a Michigan-wide *E. coli* qPCR beach notification value was established in 2019, allowing for the wide use of draft Method C in many of the state's Great Lakes beaches, and providing more rapid notification about beach water quality. Furthermore, the cities of Racine, Wisconsin and Chicago, Illinois have successfully implemented rapid qPCR methods for measuring *Enterococcus* for several years. In addition, sanitary surveys have been implemented by several Great Lakes states and tribes (including Michigan, Wisconsin, Bad River and Grand Portage Band of Lake Superior Chippewa) to determine bacterial pollution sources in recreational waters. Predictive modeling has been used to determine beach notifications in several locations. This includes the use of Nowcasting modeling methods in Minnesota and Wisconsin, Virtual Beach models in Michigan, Ohio and Grand Portage, Swimcast models in Illinois, and the development of predictive models at several beaches in Indiana. Lastly, public notification measures in states and tribes are conducted in a variety of ways including formal and informal education and outreach efforts, festivals, school and camp programs, social media, websites, mobile phone apps, QR codes, phone messaging systems, press releases, brochures, flags and multi-lingual signs (English, Spanish, Hmong and Ojibwe). Several states and tribes use BEACH data to determine best management practice and mitigation implementation plans.

In the **South Central** (EPA Region 6) region, Texas published research on long-term water quality patterns and implemented new beach water quality programs. In a recently published study (Powers et al., 2021), researchers conducted a long-term assessment of fecal bacterial pollution in the northwestern Gulf of Mexico using enterococci data spanning the Texas coast from 2009 to 2020 (66 beaches, 169 stations, and over 75,000 samples). They found that enterococci levels were correlated with time, population size, and sea level, and that 22 beaches were pollution 'hotspots' where enterococci levels frequently exceed the EPA Beach Action Value. As these patterns suggest a link between increasing bacteria levels and sea level rise, this study is being used to inform future beach management actions. Furthermore, Texas implemented a new state program called Clean Coast Texas (www.cleancoast.texas.gov), an initiative of the Texas coastal nonpoint source pollution program that aims to help communities reduce pollution and enhance water quality along the Texas coast. They achieve this by supporting sustainable stormwater

management in coastal communities, improving water quality and flood management, and providing technical resources and planning tools. Texas is also initiating three new studies related to microbial source tracking, land use, and infrastructure analysis; updating data in Texas Beach Watch (https://cgis.glo.texas.gov/Beachwatch/), which provides beach water quality updates and advisories; and conducting informal interviews with coastal decision makers.

Carmel River State Beach, California. R. Davis

In the **Pacific Southwest** (EPA Region 9), California is pursuing innovative approaches to monitoring including using predictive models, conducting studies on rapid PCR-based methods and microbial source tracking across the U.S.-Mexico border, and posting multilingual beach advisory signs in English and Spanish. California tested the application of droplet digital polymerase chain reaction (ddPCR) for detection of *Enterococcus* in coastal waters of San Diego and found that ddPCR results matched closely with the Enterolert Test for identifying exceedance levels of *Enterococcus* in coastal waters of San Diego, suggesting that this rapid method may be reliable for detecting *Enterococcus* exceedances (Crain et al., 2021). Furthermore, California used combined ddPCR and next generation DNA sequencing methods to track pollutant dynamics along the US-Mexico border. They found evidence of a gradient in fecal pollution from a wastewater treatment facility in Mexico, the spatial extent of which was dependent on ocean conditions (Zimmer-Faust et al, 2021). In addition to California, Hawaii is pursuing QMRA studies assessing alternative indicators (such as crAssphage, coliphages and human pathogens). Hawaii is also testing levels of *Clostridium* in waters in tandem with *Enterococcus*, as Hawaii maintains that *Clostridium* may be a better indicator for fecal contamination in tropical waters which have high natural background levels of *Enterococcus*. Furthermore, Hawaii is exploring environmental justice issues by mapping potential overlap between beach monitoring sites and poverty indicators.

Refuge Cove, Alaska.

In the **Pacific Northwest** (EPA Region 10), jurisdictions are pursuing innovative monitoring methods and proactive public notification measures. Oregon will carry out microbial source tracking studies in 2022 using qPCR methods to identify sources of fecal contamination at beaches that have higher rates of closures due to water quality problems. They will use the results of studies in discussions with stakeholders to spur actions to reduce bacteria levels and advisories. Washington provides technical support to local health agencies, volunteers, the public, tribes, and state and federal agencies. The state has also developed partnerships between public health agencies and volunteer organizations to implement monitoring networks, technology transfer, and education programs. Washington works cooperatively with the Makah Indian Tribe of the Makah Indian Reservation on beach monitoring efforts such as providing assistance with data entry. The Makah Indian Tribe of the Makah Indian Reservation conducts timely laboratory reporting within a 24-hour turnaround time of analytical results and works with the state of Washington to make results available for the statewide Coastal Atlas for public access. The Swinomish Indian Tribal Community has a suite of monitoring tools, including implementation of sanitary surveys to identify linkages between beach activity and exceedances, in-house laboratory processing that allows for fast processing and next-day results. Alaska has been conducting sanitary surveys to determine levels of risk in coastal recreation areas and identify pollution sources to improve beach water quality. Alaska has also been providing beach monitoring assistance to the small, remote community of Hoonah, Alaska in partnership with the Hoonah Indian Association. This partnership has enabled samples to be collected and flown out for laboratory analysis and has allowed sanitary surveys to be completed. The states and tribes in this region employ similar effective communication tools to notify the public, including posting beach advisory signs (in several languages in the case of Washington) and communicating information via websites, listservs, social media, press releases, radio ads, educational and outreach programs, pamphlets, and local community centers (e.g., Swinomish Youth Center, Hobuck Beach Resort).

Ocean City, Maryland. K. Davis.

4.3 Other Federal Agency Efforts Supporting the BEACH Act

The BEACH Act requires federal agencies that have jurisdiction over coastal recreation waters adjacent to beaches or similar points of access that are used by the public, to develop and implement monitoring and notification programs for coastal recreation waters. These programs should be designed to protect public health and safety, meet EPA's performance criteria, and address other requirements for state and local programs. In addition to EPA, federal agencies such as the Centers for Disease Control and Prevention, National Oceanic and Atmospheric Administration, National Park Service, United States Army Corps of Engineers, and United States Geological Survey carry out beach research, monitoring, or public communication efforts that, although not directly under the BEACH Act, help to support the goals of the BEACH Act either by directly implementing beach pathogen monitoring programs or indirectly supporting beach programs through research or other means. Examples of these efforts are described in this section.

Centers for Disease Control and Prevention (U.S. Department of Health and Human Services)
Centers for Disease Control and Prevention hosts a website called "Healthy Swimming" (https://www.cdc.gov/healthywater/swimming/index.html) that provides information about how to maximize the health benefits of swimming while minimizing the risk of illness and injury. This website includes links to resources for swimmers in oceans, lakes, and rivers (https://www.cdc.gov/healthywater/swimming/oceans-lakes-rivers/index.html), with state-specific resources for information on water quality advisories, beach monitoring, water quality programs, and HAB monitoring resources (https://www.cdc.gov/healthywater/swimming/water-quality-oceans.html).

National Oceanic and Atmospheric Administration (U.S. Department of Commerce)
National Oceanic and Atmospheric Administration's Marine Debris Program is the lead federal program for addressing marine debris, which includes at-sea sources such as derelict vessels and abandoned, lost, or otherwise discarded fishing gear. More information on the Marine Debris Program can be found at https://marinedebris.noaa.gov/.

National Park Service (Department of the Interior)
Among 423 total units, the National Park Service (NPS) manages 88 ocean and Great Lakes parks across 23 states and four territories, comprising over 11,000 miles of coastline and 2.5 million acres of ocean and Great Lakes waters. These ocean and coastal parks contain ecologically valuable habitats, including coral reefs, kelp forests, glaciers, estuaries, beaches, and wetlands. They also provide tremendous recreational value to the nation, attracting over 90 million visitors each year and generating over $6.9 billion in economic benefits to local communities. Park managers are confronted with multiple threats to natural and cultural resources and critical infrastructure from inside and outside of park boundaries. In response, NPS has adopted strategies to increase the agency's organizational and scientific capacity to address ocean and coastal issues in partnership with state and federal agencies and local organizations.

While the vast majority of long term NPS water quality monitoring focuses on natural resources, pathogen monitoring of recreational waters has been conducted in 30 parks, often in partnership with USGS or state, tribal and local governments. Examples of national park beaches that are monitored for *E. coli*, *Enterococcus* or fecal coliforms include Grand Portage National Monument, Indiana Dunes National Park, Sleeping Bear Dunes National Lakeshore, Apostle Islands National Lakeshore, Cumberland Island National Seashore, Fort Frederica National Monument, Fire Island National Seashore, Assateague Island National Seashore, Acadia National Park, Cape Cod National Seashore, Gateway National Recreation Area, and Fort Pulaski National Monument. In addition to monitoring, some parks also have notification programs, including Indiana Dunes National Park, Sleeping Bear Dunes National Lakeshore, Assateague Island National Seashore, Fire Island National Seashore, Gateway National Recreation Area, and Acadia National Park. More information on ocean and Great Lakes national parks can be found at https://www.nps.gov/orgs/1439/OCRB.htm.

U.S. Army Corps of Engineers (U.S Department of Defense)
The congressionally authorized National Shoreline Management Study documents the physical, economic, environmental, and social impacts of shoreline change across every coastal region of the United States. The U.S. Army Corps of Engineers (USACE) is tasked with providing technical input on current and future needs for coastal projects (https://www.iwr.usace.army.mil/Missions/Coasts/National-Shoreline-Management/). While USACE conducts testing of dredged sediment prior to placement on beaches, they do not directly monitor coastal or Great Lakes recreational waters for pathogens. Where USACE properties or structures are adjacent or overlap with coastal or Great Lakes beaches, water quality monitoring is carried out by state or local jurisdictions with ownership over those beaches. Water quality monitoring is carried out by USACE in inland recreational waters, but these locations are not subject to the BEACH Act.

U.S. Geological Survey (Department of the Interior)
USGS has conducted extensive research on microbiological water quality monitoring and modeling methods in the Great Lakes through the Great Lakes Science Center, Ohio-Kentucky-Indiana Water Science Center, Central Midwest Water Science Center and Upper Midwest Water Science Center. Since 2018, these USGS offices have collectively published nine journal articles and reports (with an additional imminent publication), four data releases, and one fact sheet. These products include findings on topics such as microbial source tracking, nowcasting modeling approaches, microbial gene sequencing, cyanobacterial toxin detection, and environmental contributors to microbiological contamination. These studies advance knowledge on innovative water quality monitoring and forecasting techniques that can be used to inform methods utilized by beach programs. A list of USGS Great Lakes Beach-related products (2018-present) can be found in the Appendix: USGS Journal Articles and Reports.

References:

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Twichell, J. H., Mulvaney, K. K., Merrill, N. H., & Bousquin, J. J. (2022). Geographies of Dirty Water: Landscape-Scale Inequities in Coastal Access in Rhode Island. *Frontiers in Marine Science*, *8*, 1-12.

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Section 5. Challenges and Opportunities

While many beach programs have implemented innovative monitoring and notification methods, states, tribes, territories, and local governments face a number of challenges that can impede successful implementation of beach monitoring and notification efforts. States have told EPA that funding shortages can limit effective program implementation and result in the inability to meet the basic needs of beach monitoring and notification programs, such as budget restraints in laboratories, constraints in posting monitoring results, and the inability to monitor all beaches. While some states employ creative solutions such as working with volunteer networks and local partners to implement monitoring programs, according to states, many need to supplement BEACH Act funding with other sources of state or federal funding to effectively implement their beach monitoring and notification programs. Currently, only 54.1% of total beaches are monitored. Jurisdictions that want to implement monitoring and notification programs at more of their publicly accessible beaches would need to identify additional resources.

There are also funding challenges for federal agencies with jurisdiction over coastal recreation waters next to beaches used by the public to meet the BEACH Act requirement. These federal agencies must maintain monitoring and notification programs and submit to EPA reports that describe the monitoring data collected and actions taken to notify the public (33 USC § 1346(d)), while working within the confines of their appropriated funds. In the future, EPA will likely need to upgrade its data systems in order to incorporate the data submitted by other federal agencies.

Jurisdictions stated that they would also benefit from expanding the scope of work authorized under BEACH Act funds. BEACH Act funds are currently not authorized for supporting programs that jurisdictions rely on, such as microbial source tracking, remediation of pollution sources, and HAB and phytoplankton biotoxin monitoring and notification in marine and freshwaters. Monitoring for HABs is part of a comprehensive sampling strategy in jurisdictions throughout the U.S., and multiple states indicated that they would like to be able to use BEACH Act funds for monitoring and notification aspects of HABs programs. In some jurisdictions, HAB occurrences are currently the primary driver of recreational beach closures.

Multiple states have identified staffing shortages as a barrier to implementing beach programs. Staffing shortages or frequent turnover of staff can result in internal program challenges, including late or incomplete data entry and reporting, less frequent sampling, difficulties in delivering samples to and from laboratories, and delays in hiring. These staffing challenges are compounded in remote areas or islands, where it can be more difficult to find qualified job applicants and proximity or access to laboratories may be limited. States with vast geographies but sparse populations face similar challenges, such as difficulties in sampling all beaches and therefore requiring local contractors to monitor beaches across the state. In states, territories and tribes with staffing challenges or shortages, additional capacity building may be useful to meet the needs of beach programs.

Additionally, some states reported to EPA there are local barriers to beach monitoring or notification. In some jurisdictions, publicly owned beaches are sampled, while those that are privately owned are not always required to be sampled, which may put swimmers at risk in private or resort beaches. Furthermore, in towns or localities where beach monitoring and notification is voluntary but not required, it can be difficult to convince these localities to implement beach monitoring and notification programs. Although there are many successful participatory science water quality monitoring programs, there is the challenge – whether perceived or real – that some concerned citizens or resource interest groups are sampling water bodies for bacteria using inappropriate methods or thresholds, leading to misleading conclusions about water quality. In these cases, states suggested that developing an EPA-approved participatory science guide or primer would be helpful to direct participatory scientists to appropriate methods and conclusions for water quality sampling.

Another challenge is that subsets of the population are not receiving the information when it is not safe to swim at a beach. Many states do not erect signs at the beach that announce warnings or closures because

of cost, infrastructure needs, vandalism (e.g., target practice), and the harsh marine environment. While all states post the information online, people without cell phones or Wi-Fi access cannot access it. Furthermore, the information posted online is mainly in English, so non-English speakers, whether residents or tourists, are not notified. And most importantly, people do not necessarily know the information even exists or where to look for it.

Additional barriers to implementing BEACH Act programs include challenges created by the COVID-19 pandemic, including staffing shortages, inability to monitor or access certain beaches and conduct outreach and education events, and reduced access for non-tribal members to enter tribal reservations, which has resulted in more severe staffing shortages for some tribes. Fifteen percent of program beaches had advisories or closings in 2020 based on COVID-19 policies to prevent the spread of the virus in crowds.

Climate change is another challenge that has increasingly caused climate-related water quality exceedances and notifications in some regions and staffing and beach access problems due to extreme climate events. Additional barriers to implementation include complex, localized environmental conditions; the lag time between sampling and results, causing delays in public notification; balancing tourism with public health risks at beaches; and aging infrastructure.

One final challenge is the assertion by some tropical jurisdictions that the indicators used in EPA's recreational criteria (*E. coli*, enterococci) do not work well in their waters due to high background levels. However, studies are underway to determine if another fecal indicator is more appropriate for tropical and sub-tropical waters.

Each of these challenges is an opportunity to further improve the programs supported by the BEACH Act and to continue to protect human health at U.S. coasts and the Great Lakes.

Madaket Beach, Nantucket, Massachusetts. B. Kramer

Appendix: USGS Journal Articles and Reports

Articles:

Francy, D.S., Brady, A.M.G, Cicale, J.R., Dalby, H.D., & Stelzer, E.A. (2020). Nowcasting methods for determining microbiological water quality at recreational beaches and drinking-water source waters. *Journal of Microbiological Methods, 175*. https://doi.org/10.1016/j.mimet.2020.105970

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Kinzelman, J., Byappanahalli, M.N., Nevers, M.B., Shively, D., Kurdas, S. & C. H. Nakatsu, C.H. (2020). Utilization of multiple microbial tools to evaluate efficacy of restoration strategies to improve recreational water quality at a Lake Michigan beach (Racine, WI). *Journal of Microbiological Methods, 178*. 10.1016/j.mimet.2020.106049.

Nakatsu, C. H., Byappanahalli, M.N., & Nevers, M.B. 2019. Bacterial community 16S rRNA gene sequencing characterizes riverine microbial impact on Lake Michigan. *Frontiers in Microbiology, 10,* 996.

Nevers, M. B., Byappanahalli, M.N., Nakatsu, C.H., Kinzelman, J.L., Phanikumar, M.S., Shively, D.A., & Spoljaric, A.M. (2020). Interaction of bacterial communities and indicators of water quality in shoreline sand, sediment, and water of Lake Michigan. *Water Research, 178*.

Nevers, M. B., Byappanahalli, M.N., Shively, D., Buszka, P.M., Jackson, P.R., & Phanikumar, M.S. 2018. Identifying and eliminating sources of recreational water quality Degradation along an urban coast. *Journal of Environmental Quality, 47*, 1042-1050.

Safaie, A., Weiskerger, C.J., Nevers, M.B., Byappanahalli, M.N., & Phanikumar, M.S. (2021). Evaluating the impacts of foreshore sand and birds on microbiological contamination at a freshwater beach. *Water Research, 190*. https://doi.org/10.1016/j.watres.2020.116671.

Zhang, J., Qiu, H., Li, X., Niu, J., Nevers, M.B., Hu, X., & Phanikumar, M.S. (2018). Real-Time Nowcasting of Microbiological Water Quality at Recreational Beaches: A Wavelet and Artificial Neural Network Based Hybrid Modeling Approach. *Environmental Science and Technology, 52*, 8446-8455.

Data Releases:

Byappanahalli, M. N., & Nevers, M.B. (2019). *16S rRNA gene sequencing and E. coli for shorelines and the Grand Calumet River, Indiana, 2015* (Version 2.0, July 2019) [Data set]. http://doi.org/10.5066/P92JWFUR.

Nevers, M. B. (2018). *Identify sources of high E. coli concentrations, Grand Calumet River Area of Concern beaches of southern Lake Michigan, 2016-2018* [Data set] https://doi.org/10.5066/P9M8Y8F3.

Nevers, M. B., & Byappanahalli, M.N. (2020). *Microbial communities and bacterial indicators for shoreline sand, sediment, and water in Racine, Wisconsin; Chicago, Illinois; and East Chicago, Indiana; 2016-2017* [Data set]. https://doi.org/10.5066/P9NFKBEB.

Nevers, M. B., Byappanahalli, M.N. & Shively, D.A. (2018). *Identify sources of high E. coli concentrations, beaches of southern Lake Michigan, 2015* (Version 2.0, July 2020) [Data set]. https://doi.org/10.5066/F7H70F3D.

Fact Sheet:

Francy, D.S., Brady, A.M., and Zimmerman, T.M. (2019). *Real-time assessments of water quality—A nowcast for Escherichia coli and cyanobacterial toxins* [Fact sheet]. U.S. Geological Survey. https://doi.org/10.3133/fs20193061.

Glossary

Clostridium - a genus of saprophytic rod-shaped or spindle-shaped usually gram-positive bacteria that are anaerobic or require very little free oxygen and are nearly cosmopolitan in soil, water, sewage, and animal and human intestines; includes many pathogenic species, e.g., those causing tetanus, gas gangrene, botulism, and other forms of food poisoning.

Coliphage - virus that infects the bacteria *E. coli*; ideal candidate for viral indicator for fecal contamination since coliphage is found in high levels in human sewage, physically similar to viruses that cause illness associated with primary contact water recreation, nonpathogenic, amenable to overnight culture methods, can be counted cheaply, easily, and quickly, similarly resistant to sewage treatment and environmental degradation as enteric viruses of concern.

Cyanotoxin - toxic compound produced by some cyanobacteria harmful algal blooms; can be harmful to humans, other animals, and the environment; toxin concentrations may become elevated before visible bloom is observed and may persist after a bloom fades; microcystins and cylindrospermopsin are two types of cyanotoxins produced by a variety of cyanobacteria species that can cause liver and kidney damage after oral exposure.

enteric virus - viruses that replicate in the gastrointestinal tract.

Enterococcus - fecal indicator bacteria used to measure the level of fecal pollution in a water sample; the bacteria lives in the intestinal tracts of warm-blooded animals, including humans; not considered harmful to humans, but their presence in the environment may indicate that other disease-causing agents such as viruses, bacteria, and protozoa may be present.

E. coli (Escherichia coli) - fecal indicator bacteria used to measure the level of fecal pollution in a water sample; species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals; bacteria found in the environment, foods, and intestines of people and animals.

HAB (harmful algal bloom) - out of control growth in freshwater or coastal waters of algae producing toxic or harmful effects on people, animals and environment.

Pathogen - a bacterium, virus, or other microorganism that can cause disease.

Pathogen indicator – a substance that indicates the potential for human infectious disease.

water quality criteria - elements of state or tribal water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use, such as recreation. When criteria are met, water quality will generally protect the designated use.