MARINE BEACHES

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1. OVERVIEW

Marine beaches are a critical component of Narragansett Bay's recreational appeal, and beach closures reduce the quality of life for residents and visitors alike. Pathogens in recreational waters and the resulting beach closures are primarily due to contaminants in wastewater and stormwater. Tracking beach closure events in Narragansett Bay serves as an indicator of public health protection and of ecosystem health. This indicator, developed in collaboration with state health departments, classifies marine beaches as High Concern or Low Concern, based on the level of use, monitoring frequency, and historic rates of closures.

Of the 37 public marine beaches in Narragansett Bay, 14 beaches were classified as High Concern and 23 as Low Concern. With 38 closure events at High Concern beaches, 2015 was the sixth highest year of the sixteen-year record. Across all years, no clear temporal trend was observed using beach closure events as a metric. Prior to 2010, closure events at High Concern beaches intensified during wet seasons, as expected. After 2010, however, precipitation did not strongly correlate with the number of closure events. The weakened relationship between closure events and rainfall after 2010 suggests that management efforts may have been effective in reducing stormwater-related contamination at High Concern beaches.

2. INTRODUCTION

Marine beaches provide significant economic, cultural, recreational, and aesthetic value. Beach waters are susceptible to contamination with harmful microorganisms that can cause health impacts such as gastroenteritis and sore throats, or even meningitis or encephalitis (Cabelli 1983, USEPA 1986, Haile 1996, Pruss 1998). State departments of health, supported by the federal Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act), conduct microbiological monitoring. The goal of the BEACH Act, administered by the United States Environmental Protection Agency (USEPA), is to reduce risks of illness in coastal waters and the Great Lakes by improving beach testing and availability of information to the public. USEPA annually awards grants to eligible states, territories, and Tribal nations to develop and implement beach water quality monitoring and notification programs for recreational beaches.

As most microbiological pathogens are difficult to measure directly, the fecal indicator bacteria *Enterococci* (typically found in the feces of warm-blooded animals and humans) serves as a proxy for pathogens in beach water monitoring. In Narragansett Bay, the Rhode Island Department of Health (RIDOH) and the Massachusetts Department of Public Health (MADPH), with BEACH Act support, monitor 37 public marine beaches for *Enterococci*.

Water at public marine beaches is sampled during the summer season (Memorial Day through Labor Day) and analyzed using Enterolert®, a defined substrate method to estimate counts of viable *Enterococci*. For beaches in Rhode Island, the single sample standard is 60 cfu per 100 ml (colony forming units per 100 milliliter) of saltwater. Prior to 2015, however, the standard was 104 cfu per 100 ml for all marine beaches (RIDOH 2016). In Massachusetts, the state health department has adopted and continues to use the standard for *Enterococci* in marine waters at 104 cfu per 100 ml for a single sample and 35 cfu per 100 ml for the geometric mean, which is calculated based on the last five nonrain impacted samples over a 30-day period (MADPH 2016). For all Massachusetts beaches, any sample that is above the state standard is considered unsafe for swimming. For Rhode Island beaches, exceeding the standard is a trigger for beach closure consideration. Beach closures in Rhode Island take additional factors into account, including history of contamination, precipitation, flushing rates, and any additional evidence of contamination.

There are limitations in the assessment of water quality at marine beaches. Management actions to close beaches are often delayed due to 24 hours of laboratory analysis that is associated with the approved analytical methods used to measure *Enterococci*. This delay means that closures are asynchronous with adverse conditions. The conditions at many beaches change significantly in a single tidal cycle, often making the bacterial count obsolete before results are available. New technical solutions are being tested, and faster methods may be available soon. For instance, Rhode Island is investigating a qPCR (quantitative polymerase chain reaction) method that amplifies and measures fecal DNA in water samples. This method could reduce the time between sampling and the availability of results to as little as six hours. The results from this investigation will provide information on the acceptability of this method and the inherent constraints, such as costs and logistics.

Sources of microbial pathogens include discharges of raw sewage from combined sewer overflows (CSOs), failing septic systems, cesspools, and wild and domestic animals. High bacterial counts are driven by watershed conditions at local and regional scales. Precipitation and impervious cover contribute to the delivery of wastewater pathogens via stormwater runoff and/or groundwater directly into Narragansett Bay or tributaries. Changes in land use have been shown to influence the number of beach closures; urbanization near beaches can negatively affect beach microbial water quality, whereas natural lands such as forests and wetlands may provide protection and reduce the number of beach closures (Wu and Jackson 2016).

Increasingly, pathogenic loads are being reduced through management practices. Engineered retention systems, green infrastructure, pet waste management, and upgrades to CSO facilities have been implemented by municipalities throughout the Narragansett Bay watershed. CSO tunnels constructed in Providence, Rhode Island, and in Fall River, Massachusetts, which store 65 million gallons and 38 million gallons respectively, divert stormwater and untreated wastewater to holding facilities during rain events, providing capacity for later wastewater treatment. Reducing CSO discharges into receiving waters is expected to decrease pathogen loadings to Narragansett Bay, with the greatest potential for improvement at urban beaches in the northern sections of the Bay. Based on observations of positive changes in the upper Providence River Estuary, the RIDOH launched the Urban Beach Initiative in 2010 to investigate the possibility of re-opening Sabin Point, Rosa Larisa, and Gaspee Point to swimming and other recreational uses. These beaches have been subject to long-term closure due to nearby sources of pathogens and high counts of *Enterococci*.

3. METHODS

The Narragansett Bay Estuary Program collaborated with the RIDOH and the MADPH to examine beach closure days (Rhode Island) and events (Massachusetts), sampling locations, and level of concern that dictates frequency of monitoring. The water quality data for public marine beaches in Rhode Island included results from 2000 through 2003 (tested for *E. coli*) and 2004 through 2015 (tested for *Enterococci*). The data for public marine beaches in Massachusetts included results from 2000 through 2015 (tested for *Enterococci*). The Estuary Program conducted geospatial analyses to investigate patterns of beach closure events in the estuary regions of the Bay (e.g., Upper Estuary, East Passage, etc.).

Beach closure data from both Massachusetts and Rhode Island were standardized into beach closure events. Regardless of the duration of a closure (e.g., one day or one week), beach closure events were considered equal for the purposes of this analysis. Length of closure is often dependent on logistical factors related to sampling and lab analysis. It is of note that closure events most likely co-vary to some extent with the frequency of sampling at a given beach location. Thus, a closure event was defined as follows: (1) One beach may have been closed for one day, and another beach for a week, but each case was attributed as a single event. (2) If the first beach re-opened one day after closure, and then closed again three days later, that closing, no matter how many days, was referred to as a separate closure event.

Monitoring frequency is generally greater for the most at-risk locations, but it may be driven by multiple objectives. For this analysis of historical data, normalization to sampling frequency was neither practical nor supportable. In general, the frequency of routine sampling has been consistent at each beach from one year to the next, making comparisons between years reasonable.

To reconcile beaches in both states within a unified context of relative health concerns, each beach was aligned with current Rhode Island and Massachusetts tier classifications. Both states have three tiers of beach classifications with Tier 1 being the highest concern and Tier 3 lowest, although they use different criteria for classification (Table 1). From those rankings, the Estuary Program consolidated all public marine beaches into two groups—High Concern and Low Concern—based on (1) 2015 monitoring frequency as a proxy for degree of risk and (2) an analysis of historical beach closure frequency (Table 1).

Table 1. High Concern and Low Concern beach classification scheme used in analysis by the Estuary Program reconciled with state tier classification systems and corresponding monitoring frequency.

	Rhode Island		**Massachusetts**	
State Tier	**Monitoring Frequency***	**Estuary Program Classification**	**Monitoring Frequency****	**Estuary Program Classification**
1	Twice per week	High Concern	More than once per week***	High Concern
2	Twice per month	Low Concern	Once per week	High or Low Concern, determined by historical pattern of beach closures
3	Once per month	Low Concern	Every two weeks or less often	Low Concern

* Per RIDOH Tier Classification as of 2015
** Per MADPH Tier Classification as of 2015
*** There are no marine beaches in Narragansett Bay classified as Tier 1 per MADPH criteria.

Tier designation is the primary factor governing frequency of sampling; however, each state has made occasional changes in risk-based tier assignments. In Massachusetts, tier classification by beach was available for each year between 2000 and 2015. Conversely, in Rhode Island, monitoring history was estimated based on the assumption that sampling began in 2002, when the number of licensed beaches in Rhode Island more than doubled. After 2002, the number of beaches monitored became relatively stable (±2 between 2002 and 2015). However, tier classifications for each year were not readily available for each beach in Rhode Island. As a result, because beaches were classified according to 2015 tier assignments, changes in beach monitoring frequency over time could limit the comparability of beach closures in this analysis.

To address this potential issue, mean historical closure events, quantified for each beach using total beach closures divided by years monitored, were compared to the 2015 tier designations. In Rhode Island, High Concern beaches were verified to have historically high closure frequency (>1.5 closure events per year). Based on this criterion, all Massachusetts beaches except Pierce's Beach were excluded from the High Concern category due to low mean closure history. The combination of 2015 tier assignments and mean historical closure events allowed for more rigorous grouping of High and Low Concern beaches.

Thus, the Estuary Program's classification scheme developed with RIDOH and MADPH (Table 1) included:

- ☑ High Concern: frequently monitored and frequent historical closure events; mean closure events per year > 1.5
- ☑ Low Concern: infrequently monitored and fewer historical closure events; mean closure events per year < 1.5

Within these groups, marine beach closure events in Narragansett Bay were measured as follows:

- ☑ Status Bay-wide (2015): Total and average beach closure events for all 37 marine beaches in Narragansett Bay per group
- ☑ Status by Estuary Region (2015): Total and average beach closure events within each region in the Narragansett Bay estuary (e.g., Upper Estuary, East Passage, etc.) per group
- ☑ Statistics across years (2000–2015):
  - ➢ Total beach closure events from 2000 to 2015 standardized by number of beaches within each estuary region, per group
  - ➢ Mean and range of beach closure events by year for High Concern beaches in Narragansett Bay
  - ➢ Mean of beach closure events by year for Low Concern beaches in Narragansett Bay
  - ➢ Mean closure events (2000–2015) for each estuary region by year per group: results compared across estuary regions

There are no licensed marine beaches in the Little Narragansett Bay study area. For the Southwest Coastal Ponds, the Estuary Program analyzed the total beach closure events between 2000 and 2015.

Trends were investigated to better understand temporal patterns and relationships with rainfall, both Bay-wide and within regions. Precipitation (inches) data were obtained from T.F Green Airport, Rhode Island, for the period between Memorial Day and Labor Day in each year from 2000 to 2015.

4. STATUS AND TRENDS

A. Narragansett Bay

Of the 37 monitored marine beaches in Narragansett Bay, 14 beaches were classified as High Concern (13 RI, 1 MA) and 23 as Low Concern (18 RI, 5 MA) (Figure 2, Table 2).

Table 2. High Concern and Low Concern beaches by estuary region. Massachusetts beaches are italicized.

Estuary Region	High Concern	Low Concern
Upper Estuary	BARRINGTON TOWN BEACH BRISTOL TOWN BEACH CITY PARK BEACH CONIMICUT POINT BEACH GODDARD MEMORIAL STATE PARK OAKLAND BEACH *PIERCE BEACH* WARREN TOWN BEACH	*CEDAR COVE* *COLES RIVER CLUB* *LEESIDE* *SANDY BEACH* *SWANSEA TOWN BEACH*
Mouth of Estuary	ATLANTIC BEACH CLUB BEACH EASTON'S BEACH SCARBOROUGH NORTH SCARBOROUGH SOUTH	CAMP GROSVENOR DUNES CLUB GOOSEBERRY BEACH HAZARDS BEACH NARRAGANSETT TOWN BEACH SACHUEST BEACH SPOUTING ROCK BEACH ASSOCIATION
Sakonnet River	PEABODYS BEACH THIRD BEACH	FOGLAND BEACH GRINELLS BEACH SANDY POINT BEACH
East Passage		CAMP ST. DOROTHY KING PARK SWIM AREA FORT ADAMS STATE PARK MACKEREL COVE BEACH
West Passage		BONNET SHORES BEACH CLUB NORTH KINGSTOWN TOWN BEACH PLUM BEACH CLUB SAUNDERSTOWN YACHT CLUB

i. Status for Marine Beaches: High Concern and Low Concern Beaches

During the 2015 season, High Concern beaches were closed for a total of 38 distinct events, and Low Concern beaches were closed for a total of 6 events. For High Concern beaches, closure events in 2015 were the sixth highest annual total on record. The Upper Estuary had the highest average of beach closure events among estuary regions in both groups (Table 3). All eight High Concern beaches in the Upper Estuary experienced one or more closure events.

Table 3. Total closure events in 2015 by estuary region in Narragansett Bay and by levels of concern. For each region, total closure events were normalized by the number of beaches in that region to produce Average Total Closure Events per beach in 2015. There were no High Concern beaches in the East and West Passages.

Estuary Region	**Total Beach Closure Events**		**Number of Beaches**		**Average Total Beach Closure Events**	
	High Concern	Low Concern	High Concern	Low Concern	**High Concern**	**Low Concern**
Upper Estuary	25	3	8	5	**3.13**	**0.60**
Mouth of Estuary	9	1	4	7	**2.25**	**0.14**
Sakonnet River	4	0	2	3	**2.00**	**0.00**
East Passage	-	0	-	4	**-**	**0.00**
West Passage	-	2	-	4	**-**	**0.50**
Narragansett Bay	38	6	14	23	**2.71**	**0.26**

Across years of beach monitoring, High Concern beaches in the Upper Estuary were characterized by the highest average total beach closure events among estuary regions between 2000 and 2015 (normalized by the number of beaches), followed by those in the Mouth of the Estuary, while High Concern beaches in the Sakonnet River had the lowest (Table 4). East Passage and West Passage did not have any beaches that qualified as High Concern.

Of the Low Concern beaches, the East Passage had the highest historical frequencies of beach closures (Table 4). Overall, Low Concern beaches were closed less frequently than High Concern beaches. While Low Concern beaches should be expected to be healthier, monitoring frequency is lower and thus Low Concern total closure events should not be compared directly to High Concern closure events.

Table 4. Total closure events from 2000–2015 by estuary region in Narragansett Bay and by levels of concern. For each region, total closure events were normalized by the number of beaches in that region to produce Average Total Closure Events per year. There were no High Concern beaches in the East and West Passages.

Estuary Region	**Total Beach Closure Events**		**Number of Beaches**		**Average Total Beach Closure Events**	
	High Concern	Low Concern	High Concern	Low Concern	**High Concern**	**Low Concern**
Upper Estuary	337	31	8	5	**42.1**	**6.2**
Mouth of Estuary	140	27	4	7	**35.0**	**3.9**
Sakonnet River	43	11	2	3	**22.5**	**3.7**
East Passage	-	61	-	4	**-**	**15.3**
West Passage	-	28	-	4	**-**	**7.0**
Narragansett Bay	520	6	14	23	**37.1**	**0.26**

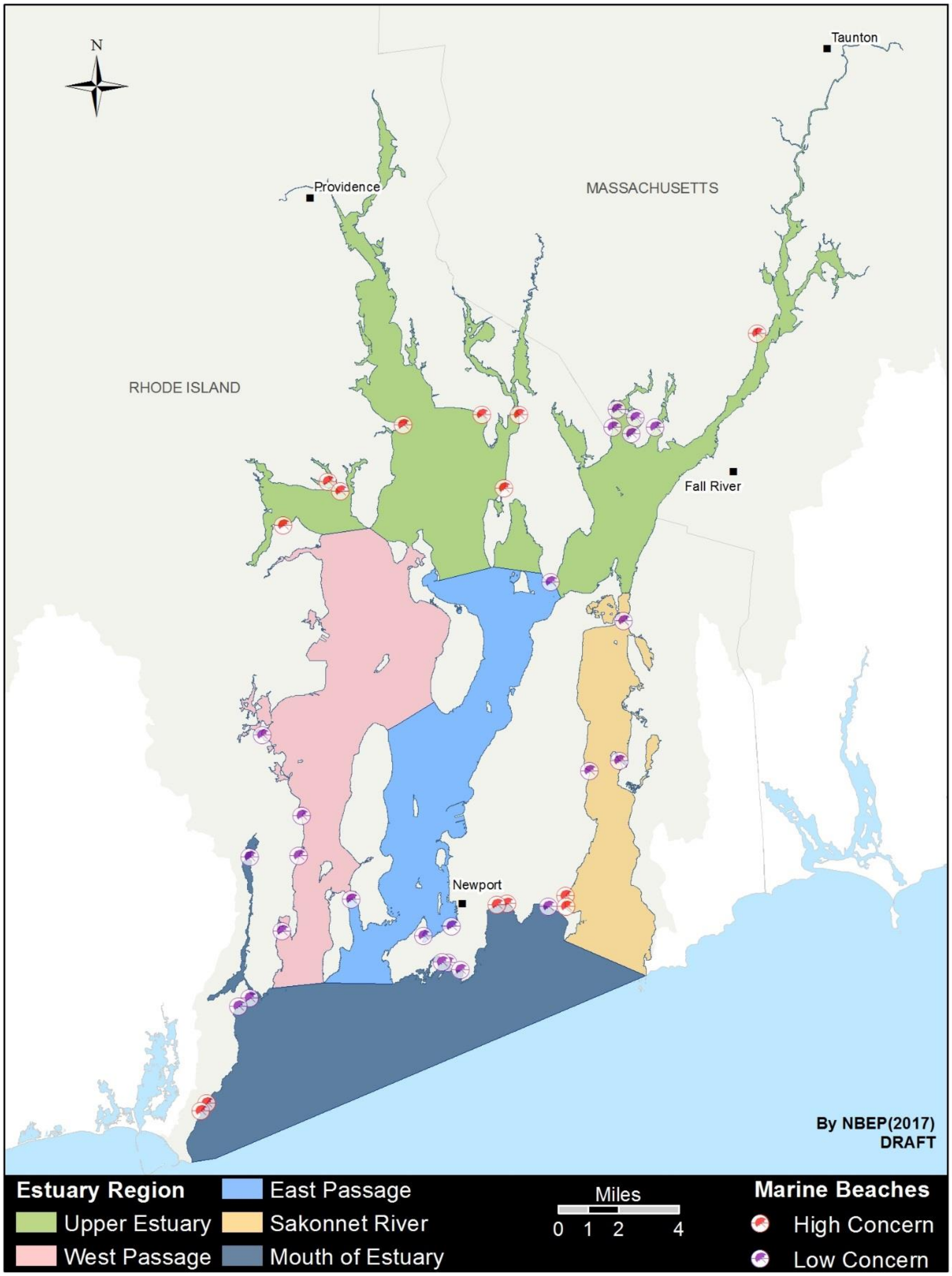

Figure 2. High Concern (red) and Low Concern (purple) marine beaches in Narragansett Bay.

ii. Trends for High Concern Marine Beaches

Analysis of High Concern beaches from 2000 to 2015 suggested that higher mean beach closure events corresponded with higher total precipitation through 2009 (Figure 3). Beach closures spiked in wet seasons (2003, 2006, 2009). After 2009, this trend of a high number of beach closures corresponding to wet years was not apparent.

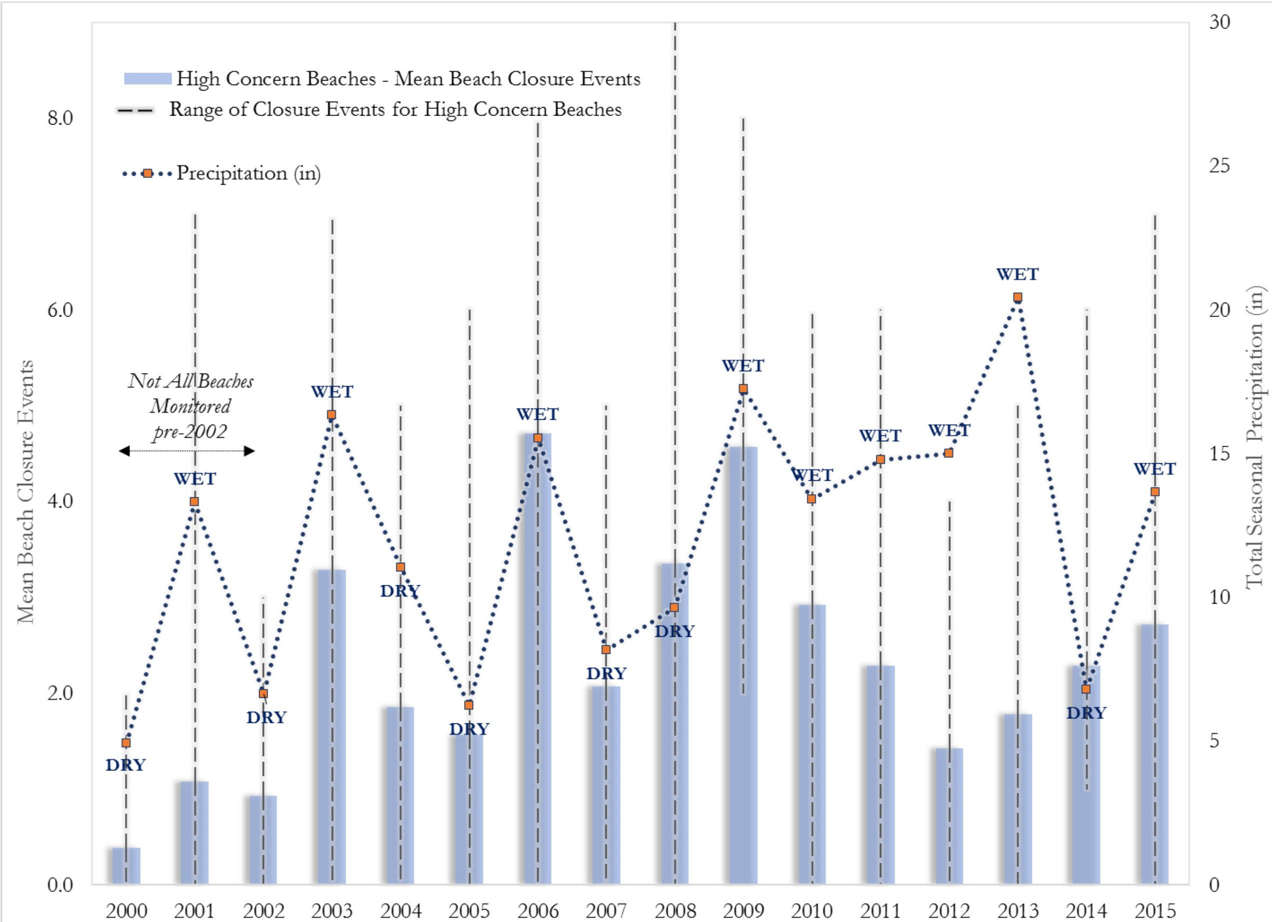

Figure 3. High Concern beaches: Mean and range of beach closure events in Narragansett Bay from 2000 to 2015. Shown with total seasonal precipitation (inches) from Memorial Day to Labor Day. Wet and dry seasons are indicated. Note: Before 2002, fewer beaches were monitored.

Regional analysis of mean closure events indicated that High Concern beaches in all regions of the Bay followed the pattern described above (Figure 4). Mean closure events in 2009 were among the highest in all regions, ranging between 4.4 and 5.5. In contrast, mean closure events for High Concern marine beaches in each estuary region during the wettest season on record (2013) were less than half, compared to 2009, with a range between 0.5 and 2.4. Across estuary regions, High Concern marine beaches in the Upper Estuary exhibited the highest annual mean closure events in the majority of years on record (including highest mean in 2015), and this pattern does not appear to be triggered only by rainfall.

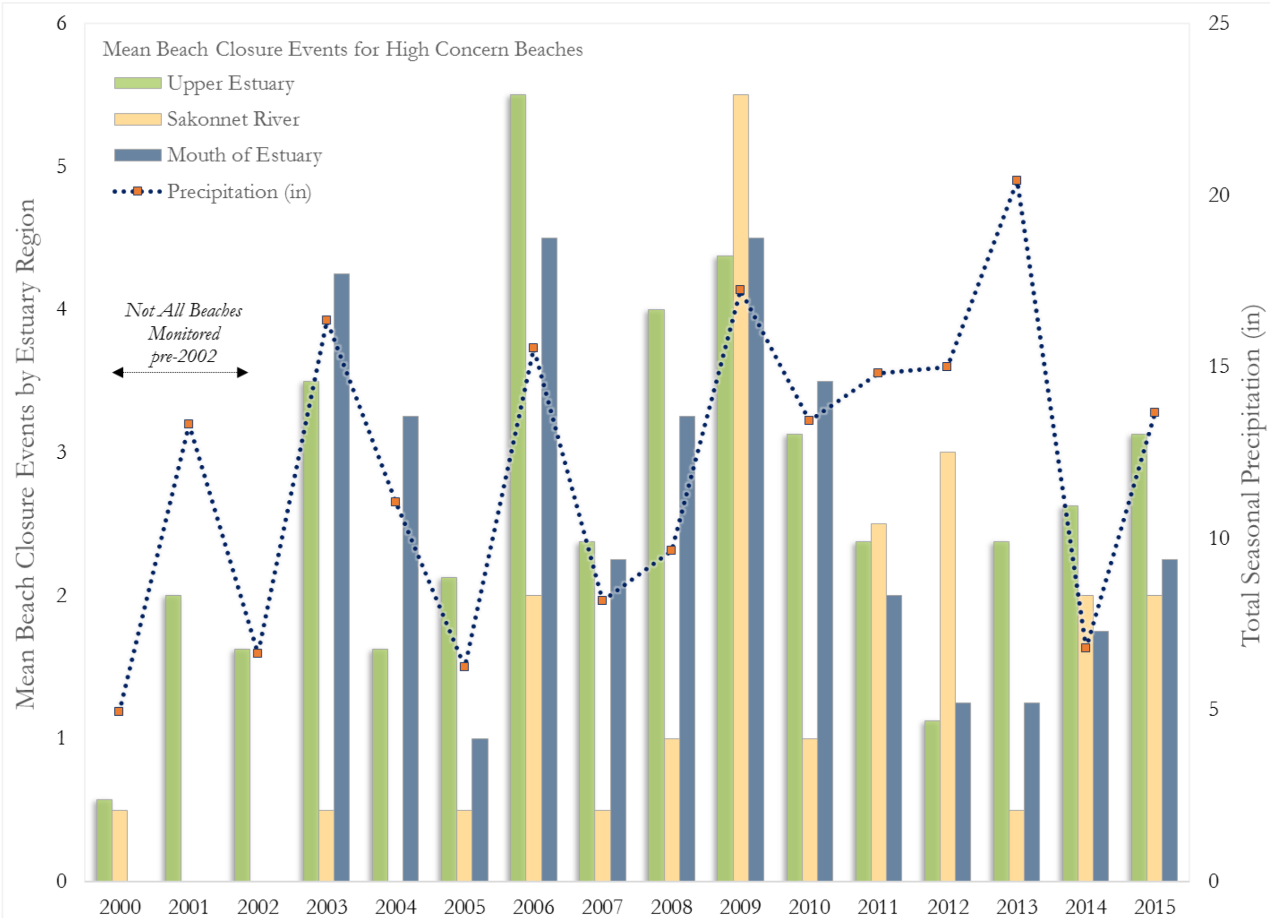

Figure 4. High Concern beaches: Mean closure events between 2000 to 2015 in Narragansett Bay for each estuary region shown with total seasonal precipitation (inches). Note: Before 2002, fewer beaches were monitored.

iii. Trends for Low Concern Marine Beaches

Among Low Concern beaches, precipitation and mean closure events appeared to be linked in most years on record (Figure 5). The magnitude of mean closure events was much lower compared to High Concern beaches, and the maximum Low Concern mean closure events observed in this record never exceeded 1 closure event per beach per year. It should be noted that mean closure events were calculated using a demonimator of 27 Low Concern beaches classified using 2015 Tier assignments (and separated by estuary region when applicable). While the denominator in this analysis was constant, in reality, it is possible that this total changed from one year to the next if beaches were re-assigned tiers. Nevertheless, the determinants of frequency of monitoring per year are largely qualitative, and so the number of beaches sampled each year can be assumed to be constant (±1) and the patterns observed are thus within reason.

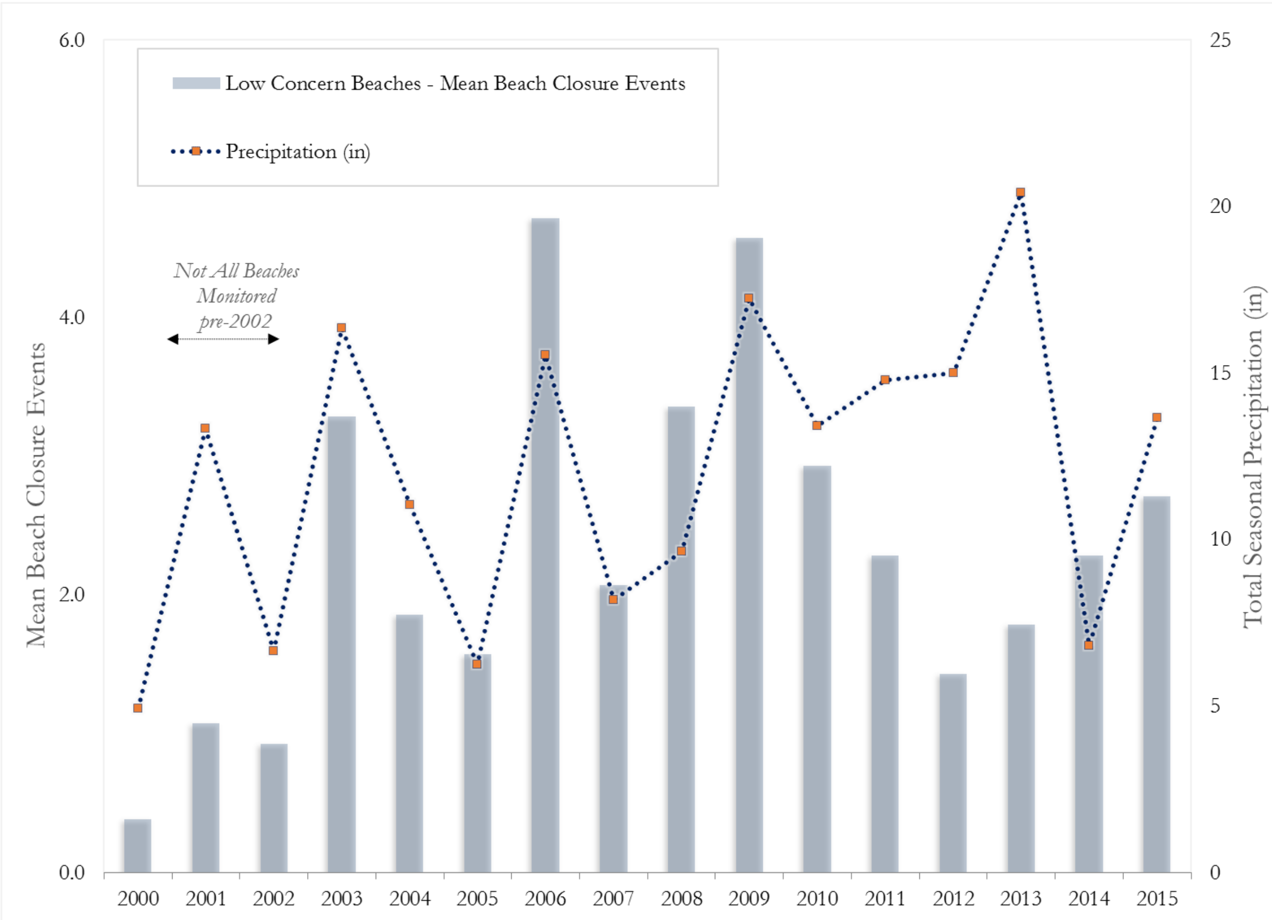

Figure 5. Low Concern beaches: Mean beach closure events between 2000 to 2015 in Narragansett Bay shown with total seasonal precipitation (inches). Note: Before 2002, fewer beaches were monitored.

The regional analysis for Low Concern marine beaches did not show patterns of mean closure events linked to rainfall (Figure 6). To detect other factors influencing closures of Low Concern beaches, we recommend an additional metric that accounts for changes in *Enterococci* CFUs per beach each year (see Data Gaps and Research Needs).

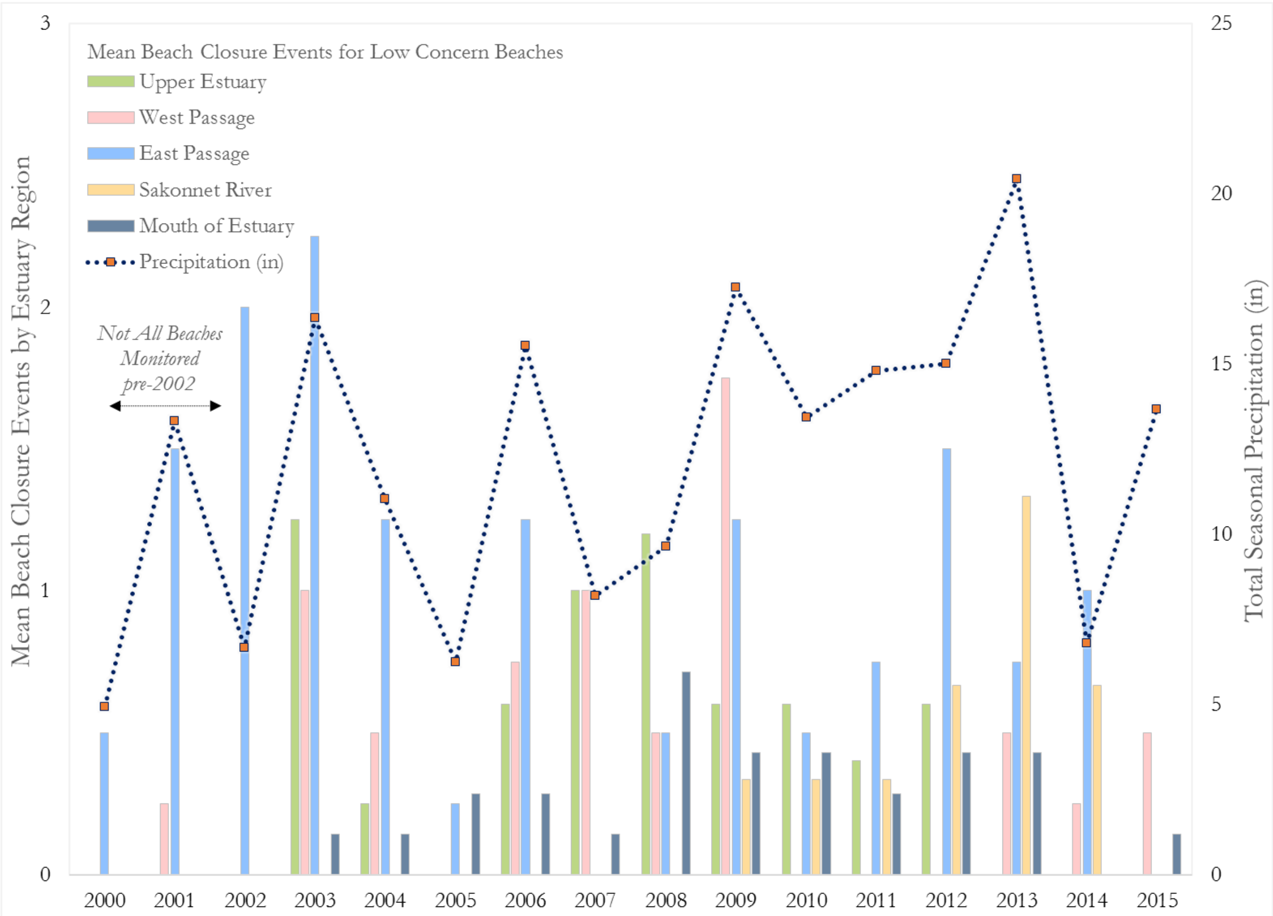

Figure 6. Low Concern beaches: Mean closure events from 2000 to 2015 in Narragansett Bay for each estuary region shown with total seasonal precipitation (inches). Note: Before 2002, fewer beaches were monitored.

B. Southwest Coastal Ponds

The Southwest Coastal Ponds have 34 licensed marine beaches, all of which classify as Low Concern. No closure events occurred during the 2015 season. The low levels of closures constrained temporal analysis; however, it appeared that to some extent rainfall may have been related to increases in closure events in 2006 and 2009.

Most of the beach closures in Southwest Coastal Ponds can be attributed to one beach, Camp Fuller–YMCA in South Kingston, although this beach experienced a low level of closures and never exceeded one closure event per season.

5. DISCUSSION

Regional analysis of 16 years of marine beach closure data in Massachusetts and Rhode Island revealed a striking record of numerous beach closure events concentrated among the 8 High Concern beaches in the Upper Estuary in Narragansett Bay, a region with high pathogen loading (Table 4). While management actions can implement solutions that mitigate localized stressors, the hydrodynamic characteristics of a beach can also have a strong impact on water quality. Beachfronts that are exposed and well-flushed, like those in the Mouth of the Estuary, are less likely to have bacterial contamination (Coakley et al. 2016). Beaches in or near the Mouth of the Estuary have greater wave action and water circulation and experience fewer beach closures than those in the Upper Estuary (Table 4). However, High Concern beaches near the Mouth of the Estuary continue to see closures despite the benefits of greater circulation. Beaches in enclosed embayments of the Upper Estuary (e.g., Greenwich Bay) with reduced circulation may experience higher closure events.

Historical patterns in closure event frequency at High Concern beaches indicate that closure events may correspond to seasonal precipitation (Figures 3 and 4). During heavy rainfall, stormwater runoff can become contaminated by interactions with animal feces (wild and pet) and untreated or poorly treated sewage (failing septic systems, cesspools, and CSOs). This runoff can discharge to waterways, bringing harmful pathogens to beaches. Results suggest that during dry seasons, beach closure events appear to fluctuate at a reduced magnitude, perhaps driven by localized and transient factors, such as subsurface transport of pathogen-contaminated groundwater (Lipp at al. 2001) or recreational contamination. As evidenced in 2006 and 2009, both of which were wet seasons, when rainfall exceeds the capacity of the system to absorb or capture runoff, closure events increase. However, after 2009 the frequency of closure events did not appear to spike during wet seasons such as 2011, 2012, and even 2013 (the wettest season in this record) (Figures 3 and 4).

The Estuary Program performed an exploratory Pearson's product-moment correlation analysis of High Concern beaches. In the analysis of the entire period from 2003 to 2015, which included all years with reliable monitoring frequency, precipitation was not correlated with mean beach closure events ($r = 0.323$, $p = 0.223$, $N = 13$). However, between 2003 and 2008 precipitation was positively correlated to mean beach closure events ($r = 0.828$, $p = 0.006$, $N = 7$), and between 2009 and 2015 no correlation was observed ($r = -0.375$, $p = 0.400$, $N = 6$). This pattern was similar when analyzed within regions of the estuary. This preliminary analysis suggests a strong positive relationship between closure events and seasonal precipitation prior to 2009, and a weakened relationship after 2009. Following further development of the beach health indicator, a robust statistical analysis that also accounts for rainfall variability will be necessary to test the validity of this observation (see Data Gaps and Research Needs).

The weakened response to precipitation among High Concern beaches after 2009 is perhaps related to reduced loads of harmful pathogens to those beaches. Watershed stressors, such as impervious cover and wastewater infrastructure, that exacerbate pathogen transport to receiving waters during rain events can be mitigated by local and regional management actions. However, additional data analysis will be needed to determine the effects of management actions on beach closure events as well as on actual pathogen loadings in Narragansett Bay waters (see Data Gaps and Research Needs).

Low Concern beaches were characterized by fewer closure events than High Concern beaches, and this may be due to the fact that Low Concern beaches are monitored less frequently. Mean beach closure events for Low Concern beaches closely followed precipitation across almost all years (Figure 5), however, it should be noted that monitoring history was not available for Rhode Island at the time of this report, thus beach closure events for Low Concern beaches are unlikely to fully describe beach health (see Data Gaps and Research Needs).

The Town of Bristol, Rhode Island, has set an example to demonstrate water quality improvements in its public beach local management strategies. In 2013, the Town completed restoration and implementation of stormwater best management practices (BMPs). Pre-BMPs, the total number of closure days at Bristol Town Beach were linked directly to rainfall events. The number of beach closures declined post-BMPs, despite an increasing trend in precipitation, from an average of eight-day per season (metric used by RIDOH) before restoration efforts to none during the summer after restoration. These efforts have had ancillary benefits such as improvement of water quality at shellfish beds immediately offshore (USEPA 2015).

A majority of the beaches in Narragansett Bay have closed at least once in the past 16 years, suggesting that beach closures may be difficult to eliminate fully in a highly developed estuary like Narragansett Bay, as the risk of excess pathogen loading is ubiquitous and controlled by a variety of localized factors. Nevertheless, recent observations made by the Estuary Program and partners indicates that efforts to mitigate contaminated stormwater runoff through sewer improvements, green infrastructure, waste managament initiatives, and other BMPs have had positive effects and have contributed to supporting the vital role that beaches play in supporting quality of life, tourism, and the economy.

Beaches in the Southwest Coastal Ponds are characterized by few closure events. The majority of those beaches are exposed and well-flushed, which is likely the primary influence (Coakley et al. 2016). Wet seasons during 2006 and 2009 may have been related to the increased closure events in those years. However, those seasons included no more than 3 closure events among the 34 beaches. These results must be considered preliminary until a complete record of monitoring history is available, as not all beaches were monitored for the full duration of 2000 to 2015 (see Data Gaps and Research Needs).

Marine beaches are likely to be susceptible to climate change stressors. More frequent and intense storms may increase the supply of contaminated stormwater runoff to beaches, particularly if heavy rainfall events exceed the capacity of existing gray and green infrastructure (see "Precipitation" chapter). Additionally, warmer temperatures increase bacterial growth, which may be an additional impact of climate change on beach water quality (Michalak 2016; see "Temperature" chapter). Increased pathogen loads and warmer conditions will likely have significant impacts on beach closures.

In addition, harmful algal blooms (including macroalgae, microalgae, and cyanobacteria) have increasingly garnered attention. Cyanobacteria blooms are more common in freshwater systems, but also occur in saltwater (Paerl et al. 2011). The toxins potentially associated with bloom events can pose risks to public health and aesthetic enjoyment. More frequent and intense storms expected as a result of climate change may increase nutrient loading from contaminated stormwater runoff, creating conditions favorable to harmful algal blooms (see "Water Quality Conditions for Aquatic Life" chapter).

Climate change may also physically alter the structure of coastlines, through sea level rise, storms, storm surge, nuisance flooding, and erosion (see "Sea Level" chapter). These changes in the coastline may contribute to higher levels of pathogen contamination as stormwater and wastewater infrastructure located along the coastline will likely be burdened by higher sea levels. Many beaches are increasingly squeezed between rising seas and expanding coastal development. Reductions in beach width diminishes recreational value for residents and visitors, and economic value to local business, towns, and states. Furthermore, the natural defenses provided by beach features to coastal buildings, roads, and other infrastucture will be compromised as beach areas recede.

6. DATA GAPS AND RESEARCH NEEDS

The Narragansett Bay Estuary Program and state health department partners are in the process of compiling a cross-state dataset that includes raw bacterial counts normalized by monitoring frequency (number of samples per season per beach) for the period of 2000 to 2015. An indicator based on raw bacterial counts may prove to be a more repeatable, consistent, and sensitive metric of beach health. In 2016, Rhode Island adopted the new, federally recommended Beach Action Value as an updated standard (decreased from 104 cfu/100 mL to 60 cfu/100 mL). These more stringent measures may result in more closure events, adding another complication to using closure events as a metric for evaluating trends. Further analysis using bacteria counts associated with sampling dates will allow for cross-comparison between years with differing monitoring frequency and regulatory stringency. A protocol is needed to evaluate bacterial counts in the context of sampling frequency. Furthemore, the results of future analyses can be compared to current findings to corroborate the preliminary trends noted in this report.

Based on outreach efforts with the state health departments, we chose not to pursue analysis of freshwater beaches. Those data were not ready to be reconciled for a supportable indicator. Currently, federal grants do not provide funds to monitor freshwater bathing beaches outside of the Great Lakes. Thus, neither state has federal funding for monitoring at freshwater beaches (MADPH 2016, RIDOH 2016). Rhode Island and Massachusetts do have limited state monitoring programs for freshwater beaches; however, the data do not support a comparable analysis at this time across the states for the 53 licensed freshwater beaches in the Narragansett Bay watershed. Freshwater beach water quality data should be analyzed for harmful bacteria, fecal, and cyanobacteria indicators associated with anthropogenic and other stressors. Because freshwater beach water quality is not monitored systematically in Rhode Island (in order words, the frequency of sampling is not as consistent as it is for marine beaches), bacteria indicators are more appropriate as opposed to number of beach closure events in order to reconcile data across the watershed. On the other hand, Massachussetts has data on closure events caused by cyanobacteria, which could be used to distinguish among stressors that drive cyanobacteria blooms.

As recent preliminary trends indicate a weakening relationship between rainfall and beach closure events, it will be important to continue to evaluate beach closures in wet years, particulartly considering a new baseline that takes into account major management actions to curb pathogen loadings into the Bay. With an indicator based on bacterial counts, we anticipate that a robust statistical analysis could address temporal trends and relationships with precipitation and other factors that influence seasonal fluctuations in beach closures, including water temperature, wastewater infrastructure, land use (Wu and Jackson 2016), and patterns in human use. Such an analysis can inform more holistic managament strategies. In addition, it is imperative to relate water quality conditions at marine beaches with those of nearby and offshore shellfishing areas.

Close analysis of existing management actions such as CSO abatements, stormwater infrastructure improvements, and waste management initiatives based on bacterial counts and sampling history as metrics are likely to be useful in informing BMPs. Improvements at specific beaches are likely related to localized management actions. Pinpointing successful management strategies such as the project in the Town of Bristol that target sources of contamination will be beneficial from economic, social, and public health perspectives.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

Cabelli, V.J., A. Dufour, L. McCabe, and M.A. Levin. 1982. Swimming-associated gastroenteritis and water quality. American Journal of Epidemiology 115(4):606–616.

Cabelli, V.J. 1983. Health Effects Criteria for Marine Recreational Waters. USEPA Document Number USEPA-600/1-80-031. Health Effects Research Laboratory, Office of Research and Development, United States Environmental Protection Agency, Research Triangle Park, North Carolina.

Coakley, E., A.L. Parris, A. Wyman, and G. Latowsky. 2016. Assessment of Enterococcus levels in recreational beach sand along the Rhode Island coast. Journal of Environmental Health 78:12–17.

Haile, R. 1996. A Health Effect Study of Swimmers in Santa Monica Bay. Santa Monica Bay Restoration Project, Monterey Park, CA.

Lipp, E.K, S.A. Farrah, and J.B. Rose. 2001. Assessment and impact of microbial fecal pollution and human enteric pathogens in a coastal community. Marine Pollution Bulletin 42(4):286–293.

Massachusetts Department of Public Health (MADPH). 2016. Marine and Freshwater Beach Testing in Massachusetts, Annual Report: 2015 Season. Retrieved from: http://www.mass.gov/eohhs/gov/departments/dph/programs/environmental-health/exposure-topics/beaches-algae/annual-beach-reports.html

Michalak, A.M. 2016. Study role of climate change in extreme threats to water quality. Nature 535:349–350.

Paerl, H.W., N.S. Hall, E.S. Calandrino. 2011. Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change. Science of the Total Environment 409:1739–1745.

Pruss, A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. International Journal of Epidemiology 27:1–9.

Rhode Island Department of Health (RIDOH). 2016. 2015 Rhode Island Beach and Recreational Water Quality Report. Retrieved from: http://health.ri.gov/publications/annualreports/2015BeachProgram.pdf

U.S. Environmental Protection Agency (USEPA). 2016. Beaches Environmental Assessment and Coastal Health Act (BEACH Act). Retrieved from: https://www.epa.gov/beach-tech/about-beach-act

USEPA. 1986. Ambient Water Quality Criteria for Bacteria – 1986. USEPA Document Number USEPA-440/5-84-002. Office of Regulations and Standards, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, DC.

USEPA and Rhode Island Department of Environmental Management. 2015. Implementing low impact development practices at Bristol Town Beach keeps the beach open and improves offshore shellfishing waters. Section 319, Nonpoint Source Program Success Story, Rhode Island. EPA 841-F-15-001KK. Washington, DC. Retrieved from: https://www.epa.gov/sites/production/files/2015-11/documents/ri_bristol.pdf

Wu, J., and L. Jackson. 2016. Association of land use and its change with beach closure in the United States, 2004–2013. Science of the Total Environment 571:67–76.