



Response of Indicator Bacteria in Great South Bay, Long Island to the Breach at Old Inlet

An Analysis of Fecal Coliforms Post Hurricane Sandy

Natural Resource Report NPS/NER/NRR—2016/1261



ON THE COVER

Photograph of the breach at Old Inlet on Fire Island National Seashore shortly after the impact of Hurricane Sandy.
Photograph courtesy of Charles Flagg, School of Marine and Atmospheric Sciences, Stony Brook University.

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Abstract

Pathogenic bacteria represent a major economic and human health concern in many of the coastal bays of Long Island, New York, where the New York State Department of Environmental Conservation monitors fecal coliform bacterial levels as a proxy for pathogenic bacteria. Here we examine how Hurricane Sandy and the breach at Old Inlet, brought about by Sandy, affected fecal coliform bacteria levels in Great South Bay, Narrow Bay, and Moriches Bay. Spatial and temporal analyses of water quality conditions before and after breach formation showed that fecal coliform bacteria levels declined in areas in close proximity to the breach once it had been established, though changes were limited elsewhere. As a result of this decline in indicator bacteria, sections of coastal bays previously uncertified for shellfish harvest, such as central Narrow Bay, warrant reevaluation as a closed or uncertified shellfish bed, as does the previous practice of closing naturally occurring breaches along the barrier islands of Long Island.

Introduction

Hurricane Sandy brought with it many adverse ecological impacts, including temporary increases in pathogenic bacteria levels in coastal waters. Shellfish harvest areas for all of Long Island were placed under precautionary closures after the storm; however, the storm also formed a breach at Old Inlet on the Fire Island National Seashore that now connects a once isolated portion of eastern Great South Bay to the Atlantic Ocean. This breach has the potential to alter local water quality conditions, especially with respect to indicator bacteria concentrations in areas susceptible to contamination in the region.

Shellfish harvesting throughout the coastal bays of Long Island represents a multi-million dollar industry. Due to the health risks, including gastroenteritis and in extreme cases mortality (Rippey 1994), associated with consuming shellfish containing pathogenic microbes, food safety is a high priority in the industry. To ensure the safety of shellfish for human consumption, the New York State Department of Environmental Conservation (NYSDEC) designates areas of coastal bays as either certified, uncertified, or seasonally certified for shellfish harvest based on potential shellfish exposure to pathogenic microbes.

Due to the complexity of identifying and measuring multiple pathogenic microbes in coastal waters (Fong and Lipp 2005), fecal coliform bacteria are typically used as indicator organisms in water quality surveys, as sewage and non-point source runoff containing enteric pathogens are typically a major source of contamination. If fecal coliform bacteria are found above regulatory concentrations, it is assumed that enteric pathogens will also be present and thus may have contaminated local shellfish stocks.

Bivalve molluscan shellfish, such as clams and oysters, can pose a health risk as vectors for pathogenic microbes as they are often consumed raw or lightly cooked (Rippey 1994). When filtering water for food particles, shellfish may accumulate any microbial pathogens present in local water bodies into their tissues at concentrations many times greater than background levels (Metcalf et al. 1979). Pathogenic microbes often enter shellfish habitat via sewage contamination or through the run-off of animal waste from land, and microbe concentrations can be influenced by a number of factors including particulate matter concentration, rainfall, light intensity, salinity, and water residence time (Campos et al. 2013). Increases in pathogenic microbes have also been linked to the density of human population, amount of developed land, and amount of impervious surfaces in catchments surrounding coastal bays (Mallin et al. 2000, 2001), as well as the presence of septic systems (Lipp et al. 2001).

Of particular relevance to this study are the effects of water residence time and salinity on levels of pathogenic microbes. Residence time has been used as a component in modeling the fate of indicator bacteria in coastal systems (Steets and Holden 2003, Kashefipour et al. 2006), and lower indicator bacteria levels have been observed in systems with greater flushing and oceanic inputs (Reeves et al. 2004). Higher salinity may also lead to declines in pathogenic microbes, as indicator bacteria decay rates have been shown to be faster in seawater as compared to freshwater (Anderson et al. 2005).

The majority of Narrow Bay, which connects the eastern portion of Great South Bay to Moriches Bay on the south shore of Long Island, NY, is currently either uncertified for shellfish harvest or only seasonally certified. However, a recent increase in salinity within the region observed in a preliminary analysis indicates that the breach at Old Inlet, which was formed during Hurricane Sandy, has potentially increased the input of oceanic water into Narrow Bay (Fig. 1). This new influx of oceanic water into Narrow Bay may potentially reduce the exposure of local shellfish to pathogenic microbes by more frequently flushing out contaminated coastal waters, reducing water residence time (Steets and Holden 2003, Campos et al. 2013).

Here we present analyses of changes in fecal coliform bacteria following the breach. The primary objective in conducting this study was to evaluate the response of fecal coliform indicator bacteria to the new breach and the associated increases in salinity and improved circulation, using aspects of NYSDEC shellfish harvest area standards as a metric of potential increases in shellfish food safety. A trend of improving conditions within areas influenced by the breach may warrant a reevaluation by NYSDEC of the shellfish harvest status as part of the NYSDEC's Bureau of Marine Resources shellfisheries section's ongoing food safety efforts, which include annual and triennial evaluations of water quality data to determine if shellfishing areas meet state and national fecal coliform standards.

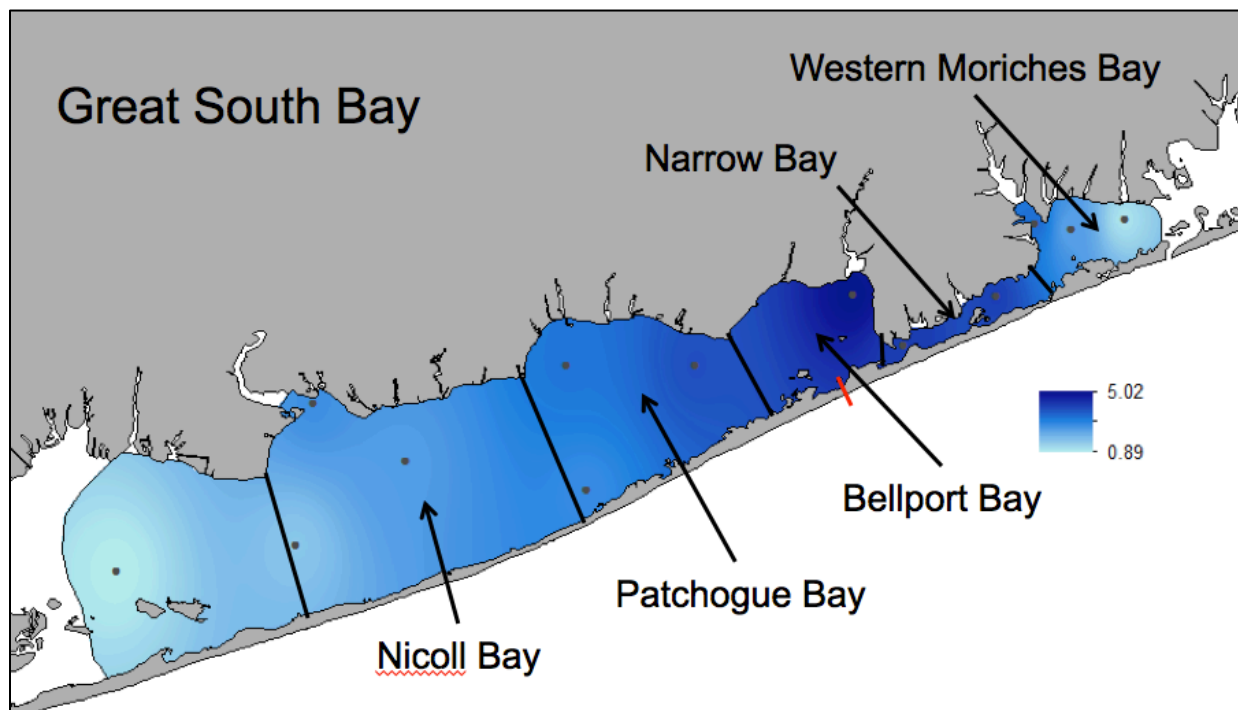


Figure 1. Increases in salinity (psu) following the breach at Old Inlet (red). Increases are concentrated in eastern Great South Bay and Narrow Bay. Data were obtained from the Suffolk County Bureau of Marine Resources for the years 2000-2014. Basins of focus in this study are shown.

Methods

Fecal coliform data provided by the NYSDEC were examined from shellfish growing regions 5 through 8, extending from Nicoll Bay (5) in Great South Bay to Moriches Bay (8). Data were obtained for 2010-2014, with January 2010 through October 2012 used as a baseline for conditions prior to the formation of the new breach. Data from November 2012 through December 2014 were analyzed to identify any effects of the new breach and associated changes in salinity and circulation on fecal coliform levels.

For the majority of sites, samples were collected approximately monthly, although some extended gaps in sampling existed following storm events as well as during certain seasons depending on site location. Normally NYSDEC endeavors to schedule at least 7 sampling runs per year in certified areas and 1 sampling run per month in seasonally certified areas. Seasonally certified areas are typically open for harvesting during the colder weather months from November through April, with “open” and “close” dates that vary from area to area by 2 to 6 weeks. Sampling sites analyzed were divided between areas that were designated as either closed year-round or seasonally closed to shellfish harvest and those normally open to harvest. A component of the NYSDEC regulations on shellfish harvest areas states that coastal waters are unapproved for shellfish harvest if the 90th percentile value for samples at a site have a geometric mean fecal coliform MPN (most probable number) per 100 ml greater than 49. Within this study the 49 MPN / 100 ml standard is used as a reference point to judge the severity of pathogenic bacteria levels following major storm events.

For each shellfish growing region, all sites from each management category were selected and data for each group of sites were plotted as a whole for the time periods mentioned above. All sites from Narrow Bay were also identified and plotted, as the bay is almost entirely uncertified or only seasonally certified for shellfish harvest. Areas of Moriches Bay located to the west of Moriches Inlet were also examined separately, as this likely represents the eastern limit of the influence of the new breach in the bay. To complete a more detailed analysis of indicator bacteria in Narrow Bay, daily precipitation data at the MacArthur Airport were obtained from the National Weather Service. These data were plotted with fecal coliform data to identify how major precipitation events may have influenced indicator bacteria levels within the Bay following the formation of the new breach. Rainfall data were also analyzed using ANOVA to identify any significant differences in average rainfall between years that may have skewed fecal coliform levels.

GIS plots were created in ArcGIS v10.0 using data from all sampling sites examined. Inverse distance weighted interpolation was used to identify spatial trends between points. Interpolation was performed on mean fecal coliform levels at each site before and after formation of the new breach, as well as the percent change observed at each site. For these analyses post-breach conditions were defined as February 2013 onwards in order to reduce any effects of initial, temporary shifts in breach structure and better reflect future conditions after the breach became more fully established.

Results

Region 5: Nicoll Bay

Areas Uncertified or Seasonally Certified for Shellfish Harvest

Prior to the formation of the new breach, peak fecal coliform levels in 2010, 2011, and 2012 exceeded 1200 MPN/100 ml at sites uncertified or seasonally certified for shellfish harvest. Peak fecal coliform levels fell to 460 MPN/100 ml in 2013, and decreased further to 240 MPN/100 ml in 2014 (Fig. 2). Despite this decrease fecal coliform levels remained well above the 49 MPN/100 ml NYSDEC standard after the formation of the breach.

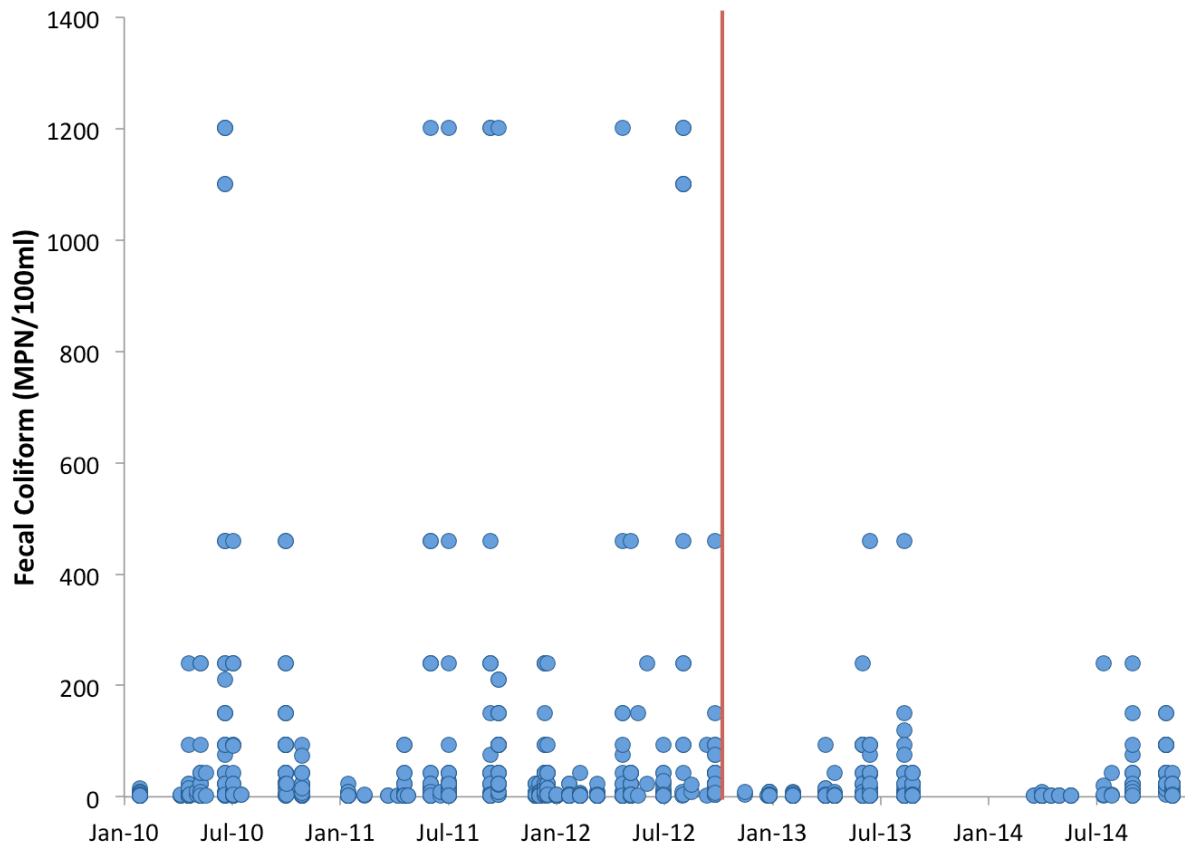


Figure 2. Region 5 (Nicoll Bay) fecal coliform data from uncertified and seasonally certified shellfish harvest areas. Vertical bar indicates new breach formation. A long-term decrease was seen in peak fecal coliform levels after the formation of the new breach, though readings remained well above the 49 MPN/100 ml NYSDEC standard.

Areas Certified for Shellfish Harvest

Peak fecal coliform levels showed little change after the formation of the breach at sites certified for shellfish harvest, remaining below 49 MPN/100 ml. 2010 and 2012 fecal coliforms levels peaked at 23 MPN/100 ml, while 2011 levels peaked at 43 MPN/100 ml. After the formation of the new breach, 2013 and 2014 fecal coliform levels peaked at 43 MPN/100 ml (Fig. 3).

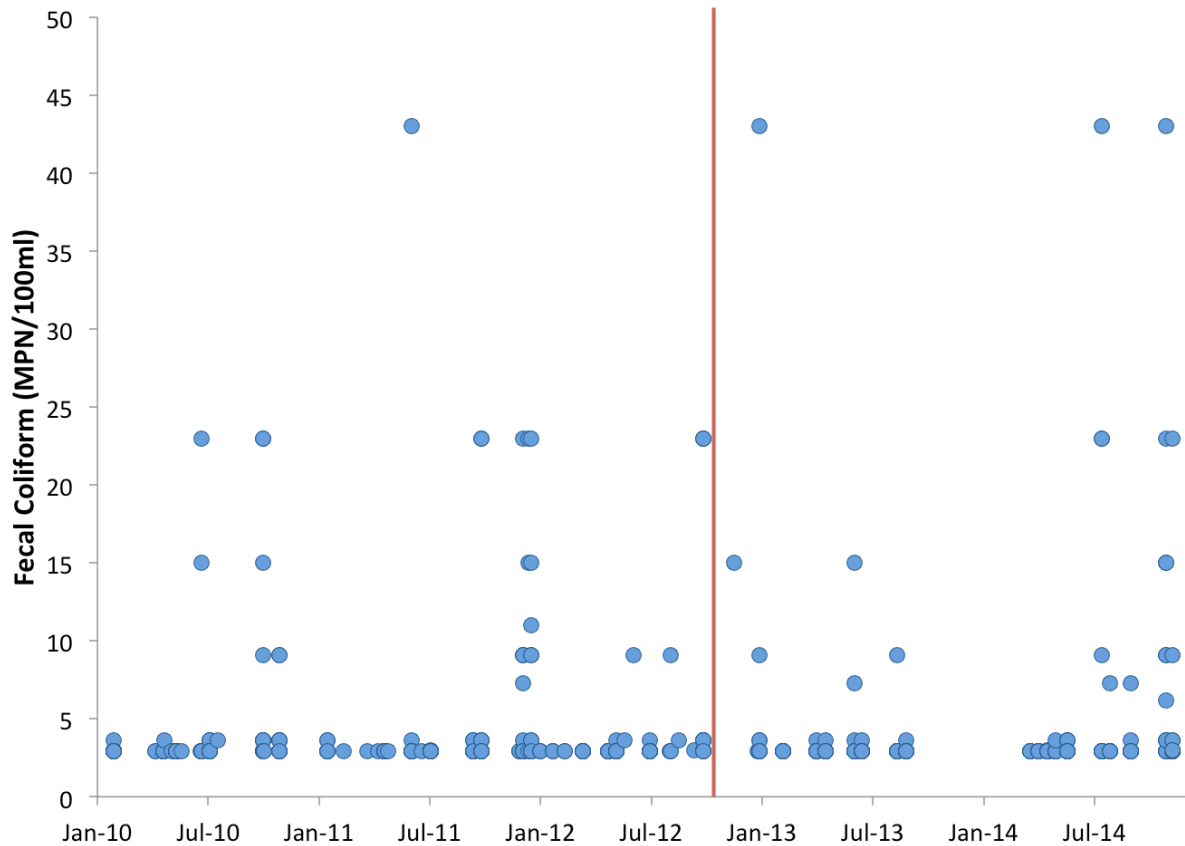


Figure 3. Region 5 (Nicoll Bay) fecal coliform data from certified shellfish harvest areas. Vertical bar indicates new breach formation. Little change in peak fecal coliform levels was observed after the formation of the new breach.

Region 6: Patchogue Bay

Areas Uncertified or Seasonally Certified for Shellfish Harvest

Peak fecal coliform levels at sites uncertified or seasonally certified for shellfish harvest displayed a decline in the year following the formation of the new breach, but then returned to levels seen prior to breach formation. 2010, 2011, and 2012 peak fecal coliform levels all surpassed 1100 MPN/100 ml. Peak levels in 2013 declined to 460 MPN/100 ml, but rose above 1100 MPN/100 ml again in 2014. Peak fecal coliform levels for all years examined frequently exceeded the 49 MPN/100 ml standard for shellfish harvest (Fig. 4).

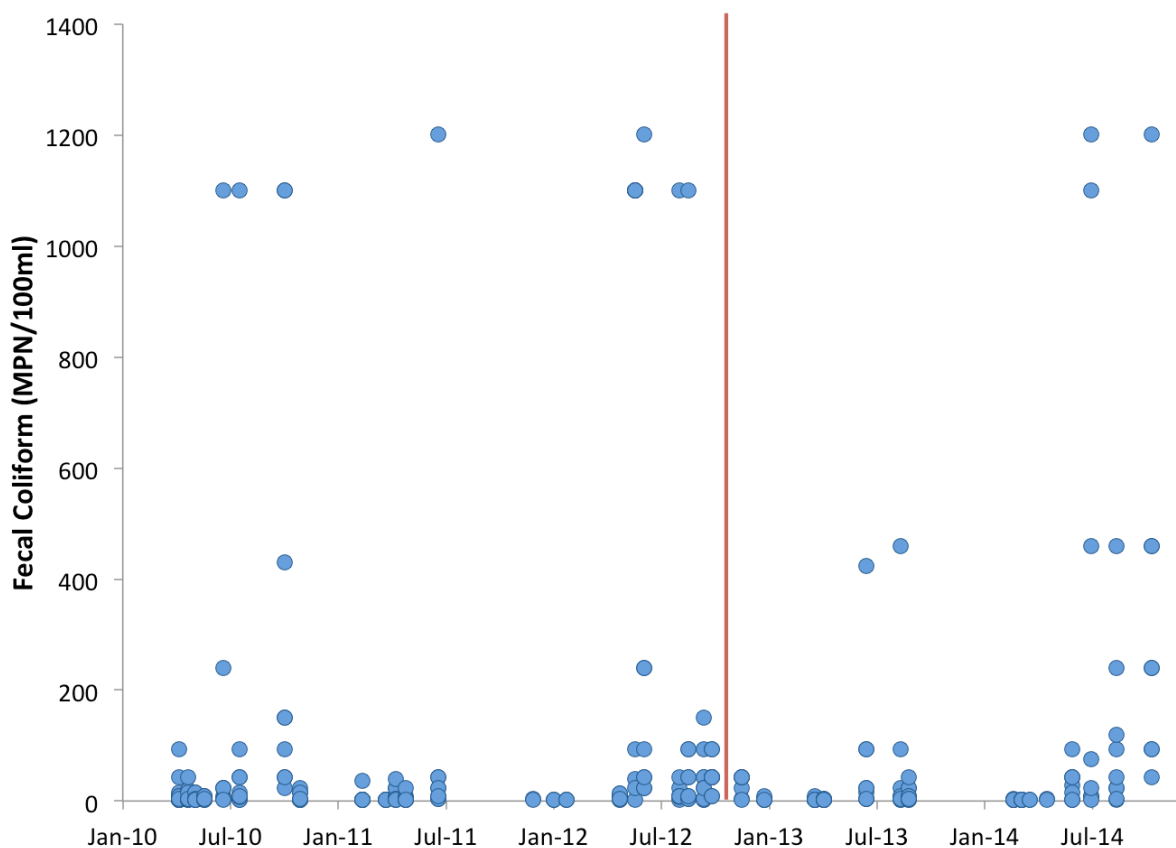


Figure 4. Region 6 (Patchogue Bay) fecal coliform data from uncertified and seasonally certified shellfish harvest areas. Vertical bar indicates new breach formation. Peak fecal coliform levels decreased in 2013, but returned to pre-breach levels in 2014.

Areas Certified for Shellfish Harvest

Fecal coliform levels at certified sites in Region 6 were higher overall than certified sites in other regions examined. Peak fecal coliform levels varied from year to year. 2010 levels reached 150 MPN/100 ml, while 2011 and 2013 levels peaked at 93 MPN/100 ml. 2012 and 2014 peak levels were more extreme, reaching 1100 MPN/100 ml or greater (Fig. 5). As these more extreme peak fecal coliform levels occurred both before and after the formation of the new breach, there is limited evidence that the breach impacted indicator bacteria within these areas of Patchogue Bay.

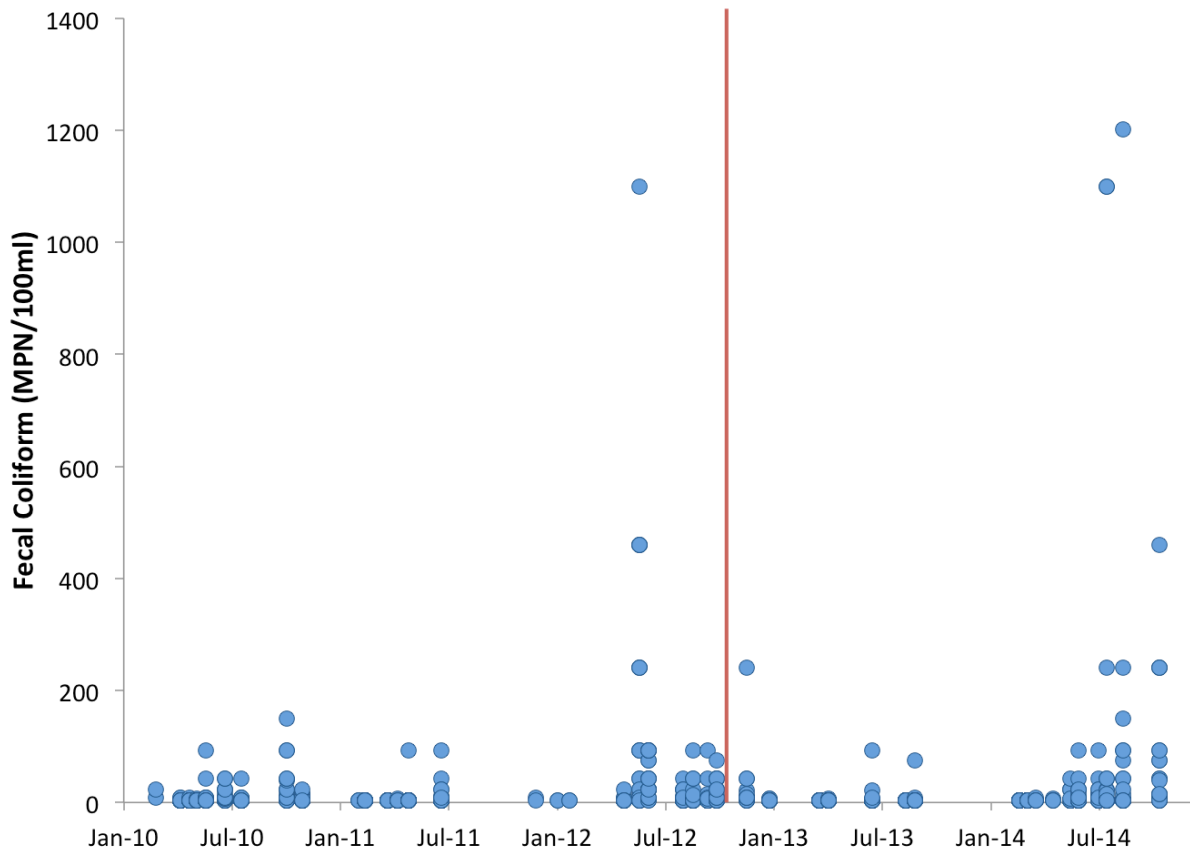


Figure 5. Region 6 (Patchogue Bay) fecal coliform data from certified shellfish harvest areas. Vertical bar indicates new breach formation. Elevated fecal coliform levels were seen both before and after the formation of the new breach.

Region 7: Bellport Bay

Areas Uncertified for Shellfish Harvest

Peak fecal coliform levels at uncertified or seasonally certified sites in Region 7 displayed a similar trend to Region 6, as 2013 levels decreased but 2014 levels returned to pre-breach conditions. Prior to the formation of the new breach, fecal coliform levels peaked at 460 MPN/100 ml in 2010, 240 MPN/100 ml in 2011, and 1201 MPN/100 ml in 2012. Peak levels fell to 75 MPN/100 ml in 2013, but levels increased to 460 MPN/100 ml in 2014. Even with the decline observed in 2013, fecal coliform levels exceeded 49 MPN/100 ml in all years (Fig. 6).

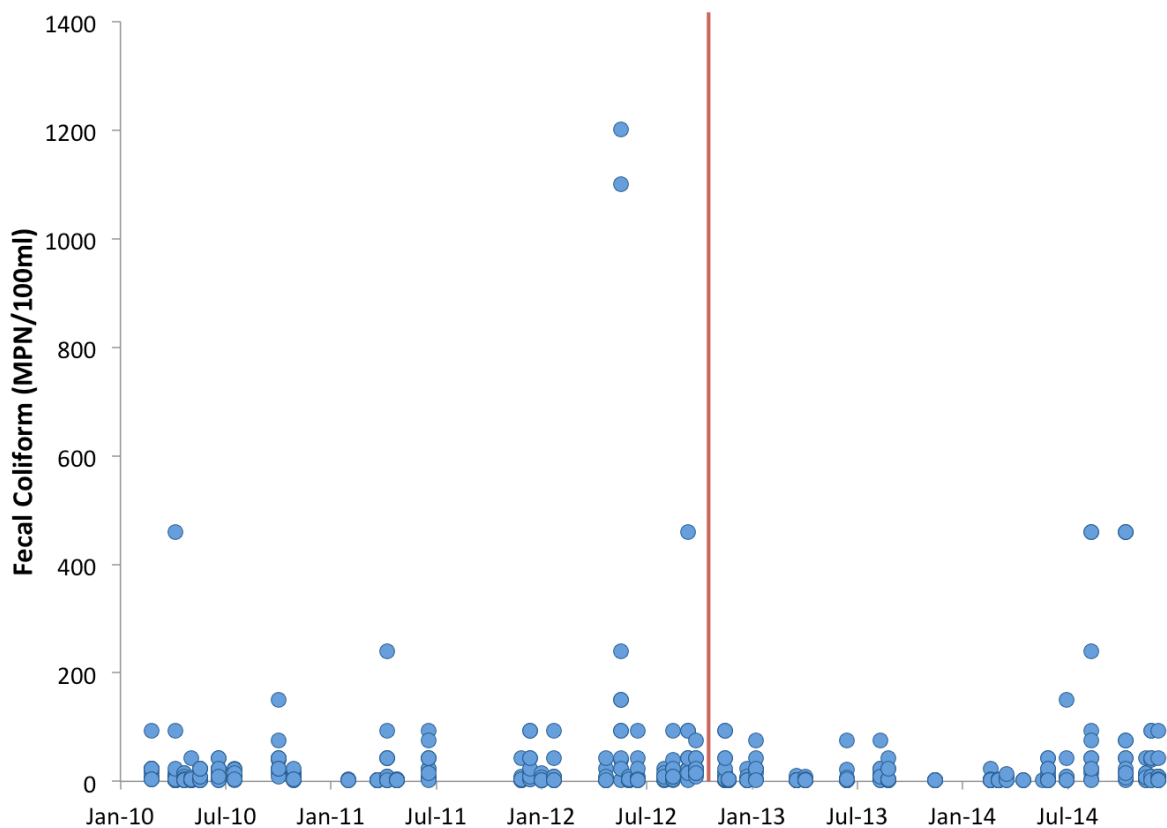


Figure 6. Region 7 (Bellport Bay) fecal coliform data from uncertified and seasonally certified shellfish harvest areas. Vertical bar indicates new breach formation. Peak fecal coliform levels decreased in 2013 but returned to pre-breach levels in 2014.

Areas Certified for Shellfish Harvest

The vast majority of samples taken from certified sites in 2010-2014 remained below 49 MPN/100 ml, with a few exceptions each year. 2010 and 2011 fecal coliform levels peaked at 93 MPN/100 ml, while 2012 levels peaked at 240 MPN/100 ml shortly before the formation of the new breach. 2013 fecal coliform levels peaked at 75 MPN/100 ml in January, but did not exceed 15 MPN/100 ml for the remainder of the year. Peak fecal coliform levels in 2014 rose to 150 MPN/100 ml, but all other readings remained below the 49 MPN/100 ml threshold (Fig. 7).

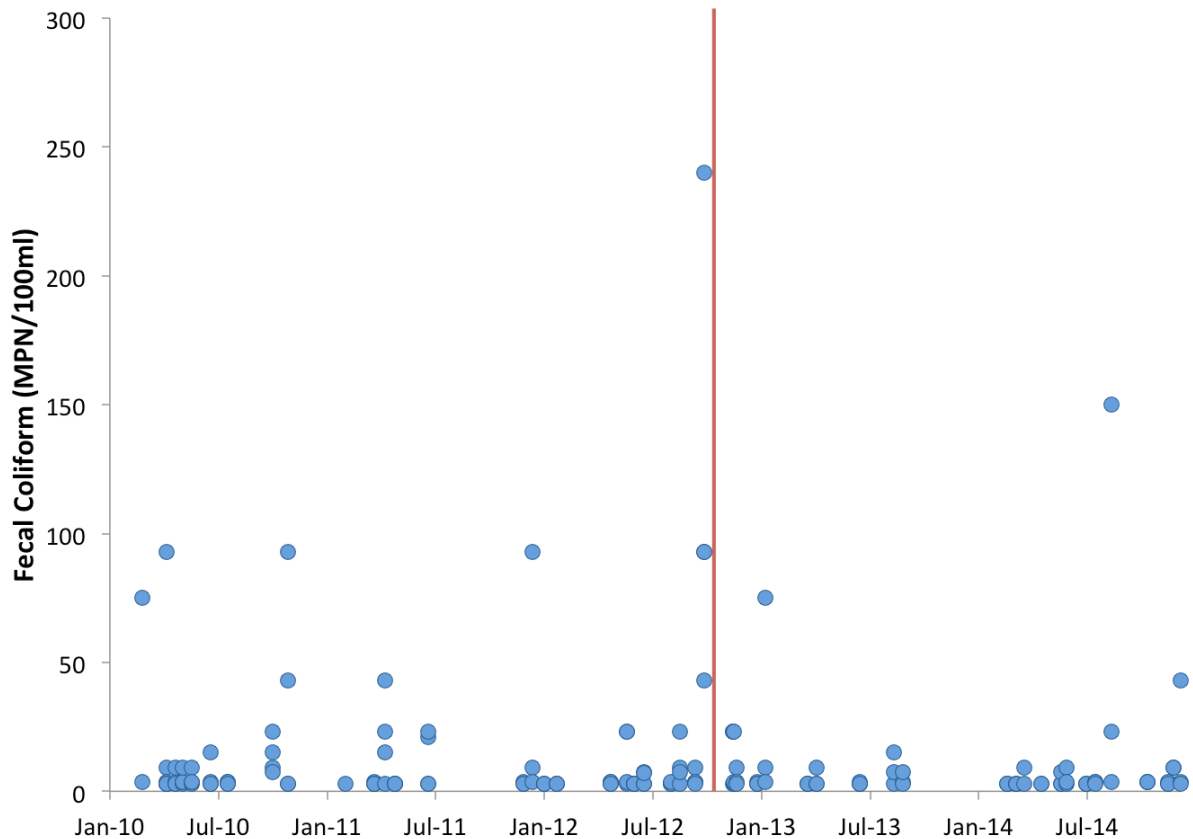


Figure 7. Region 7 (Bellport Bay) fecal coliform data from certified shellfish harvest areas. Vertical bar indicates new breach formation. Peak fecal coliform levels are depressed for much of 2013, but elevated levels are observed in 2014, similar to pre-breach conditions.

Narrow Bay

All sampling sites

Narrow Bay was the only area examined where previously uncertified or seasonally certified sites showed a decline in indicator bacteria sufficient enough to warrant reconsideration for shellfish harvest. Prior to the formation of the new breach fecal coliform levels peaked at 75 MPN/100 ml in 2010, 460 MPN/100 ml in 2011, and 93 MPN/100 ml in 2012. After the breach levels remained elevated in January 2013 at 150 MPN/100 ml, but beyond that no reading in 2013 or 2014 surpassed 49 MPN/100 ml. Precipitation data showed no significant differences in average daily precipitation levels between years ($p = 0.673$), and little difference was seen in major precipitation events after the formation of the new breach save for an extreme event in August 2014, indicating that the new breach and associated increased salinity and circulation may be important factors contributing to the reduced levels of indicator bacteria in the region (Fig. 8).

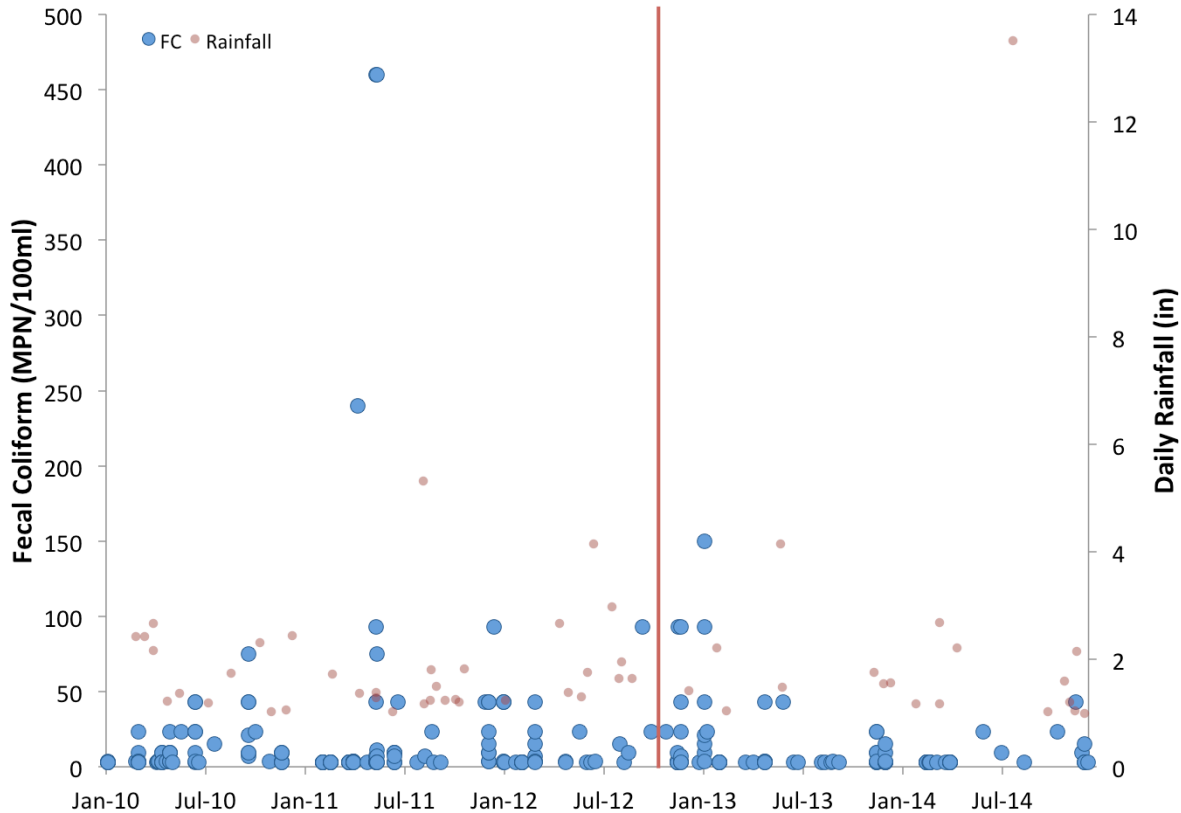


Figure 8. Narrow Bay fecal coliform data from all sampling sites and major precipitation events (>1in). Vertical bar indicates new breach formation. Fecal coliform levels fell below the 49 MPN/100 ml NYSDEC standard after breach formation, despite rainfall events.

Western Moriches Bay

Areas Uncertified or Seasonally Certified for Shellfish Harvest

Uncertified and seasonally certified sites in the western portion of Moriches Bay showed peak fecal coliform levels well above NYSDEC standards both before and after the formation of the new breach (Fig. 9). 2010 and 2011 fecal coliform levels reached 240 and 460 MPN/100 ml respectively. Peak levels declined slightly to 150 MPN/100 ml in 2013, but rose above 1000 MPN/100 ml in 2014. These peak levels were not observed throughout the year, although a number of samples in each year surpassed the 49 MPN/100 ml limit for shellfish harvest.

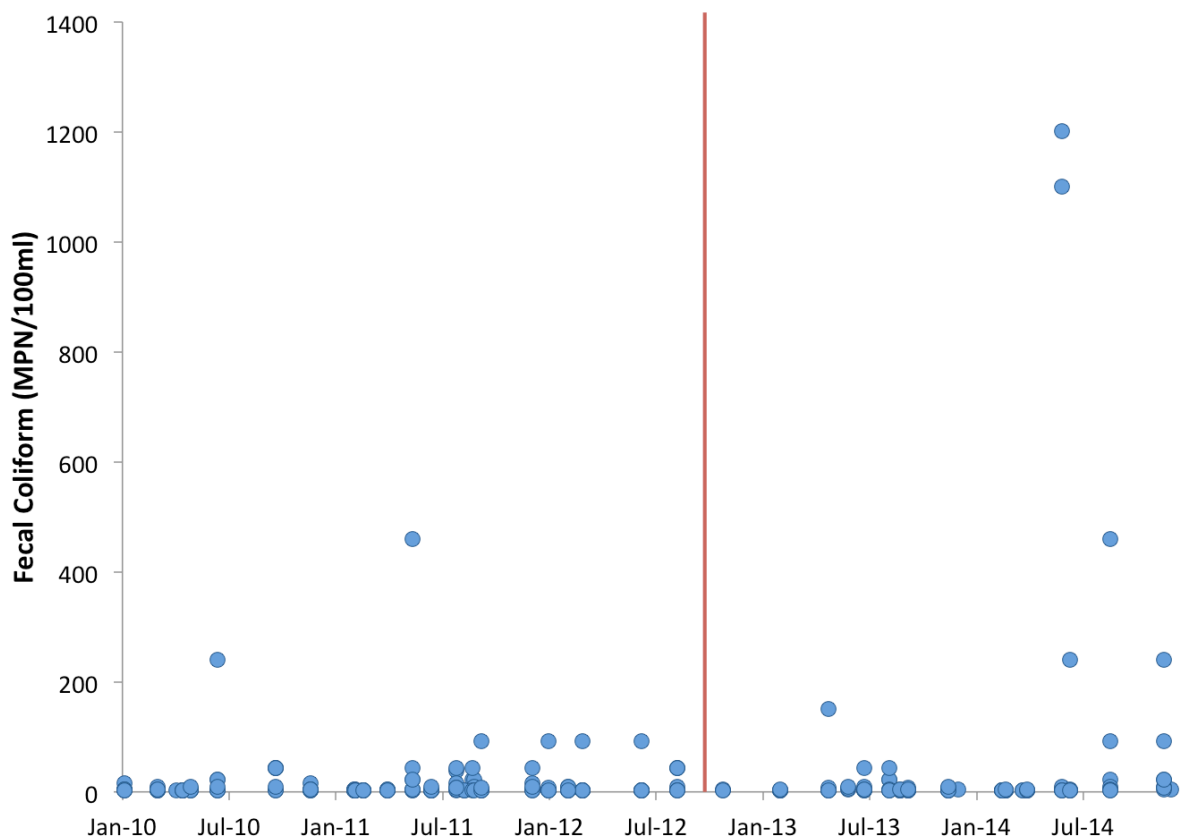


Figure 9. Fecal coliform data from uncertified and seasonally certified shellfish harvest areas in western Moriches Bay. Vertical bar indicates new breach formation. Peak fecal coliform levels extend beyond acceptable standards both before and after the formation of the new breach.

Areas Certified for Shellfish Harvest

Peak fecal coliform levels at sites certified for shellfish harvest in western Moriches Bay showed little change before and after the formation of the new breach (Fig. 10). Fecal coliform levels in 2010 and 2011 both peaked at 43 MPN/100 ml. Peak levels then rose slightly in 2013 to 75 MPN/100 ml, but fell to 23 MPN/100 ml in 2014. The peak in 2013 is the only sample recorded that extended beyond the 49 MPN/100 ml standard for shellfish harvest.

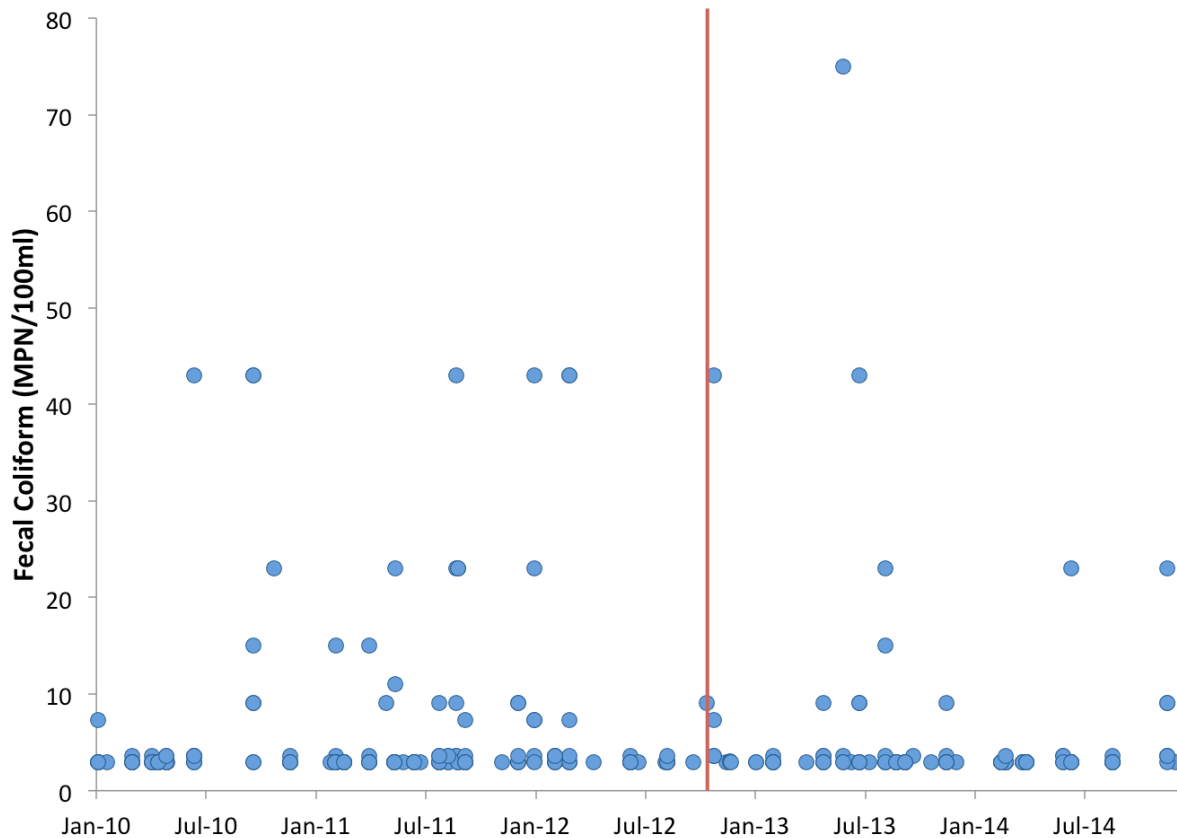


Figure 10. Fecal coliform data from certified shellfish harvest areas in western Moriches Bay. Vertical bar indicates new breach formation. Peak levels increased slightly in 2013, but the majority of readings remained within shellfish harvest limits.

GIS Analyses

Spatial analyses displayed similar results, notably with regard to the decline in fecal coliform levels observed in Narrow Bay. While areas to the east and west of Narrow Bay showed isolated changes in fecal coliform levels, potentially due to variation at sites year to year, Narrow Bay and southeast Bellport Bay were the largest areas with a consistent decline in mean fecal coliform levels post-breach (Fig. 11). Additional declines were seen in areas further west, but fecal coliform levels at the majority of these sites remained above acceptable shellfish harvest standards (Fig. 12).

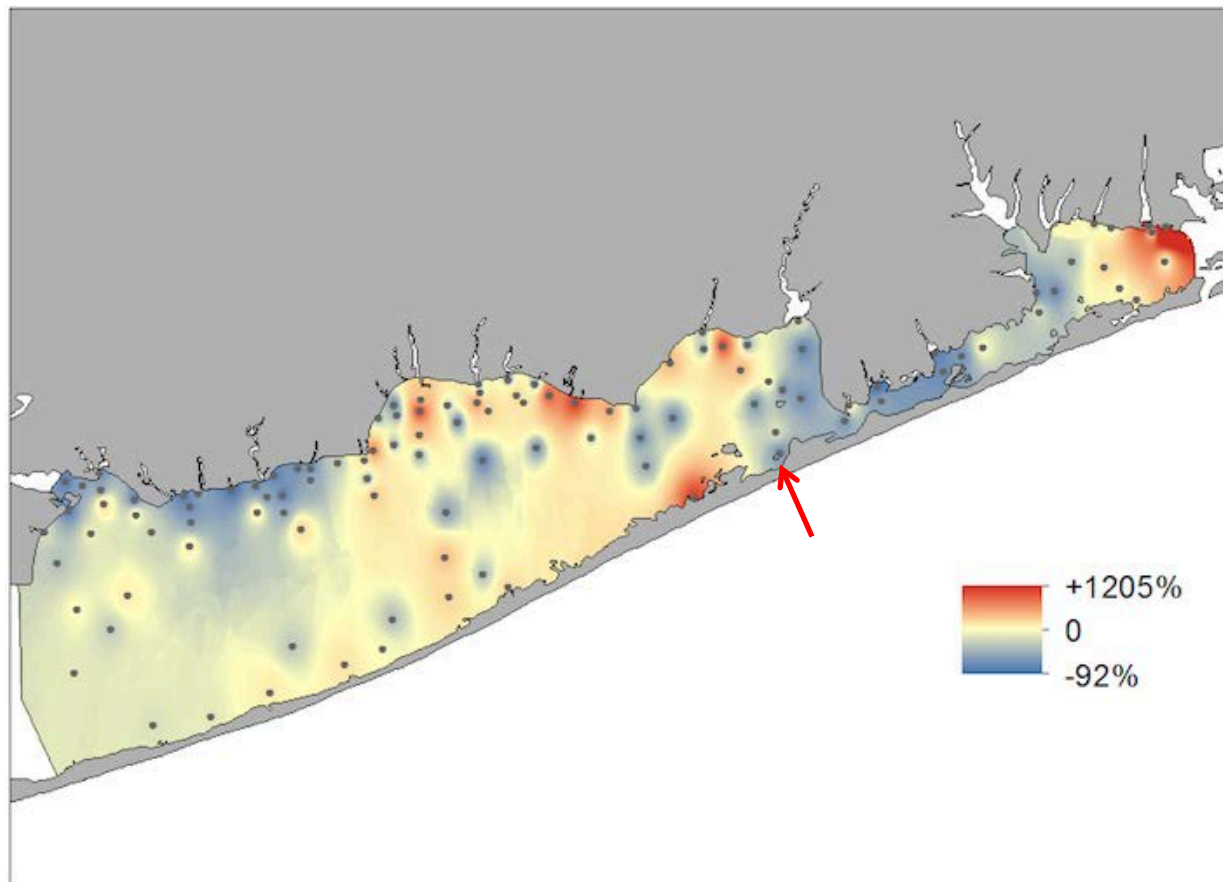


Figure 11. Percent change in mean fecal coliform levels before (2010 - October 2012) and after (February 2013 – 2014) the formation of the new breach (red arrow). Interpolation between points generated through inverse distance weighting. A decline in mean fecal coliform levels is seen from the site of the new breach east into Narrow Bay.

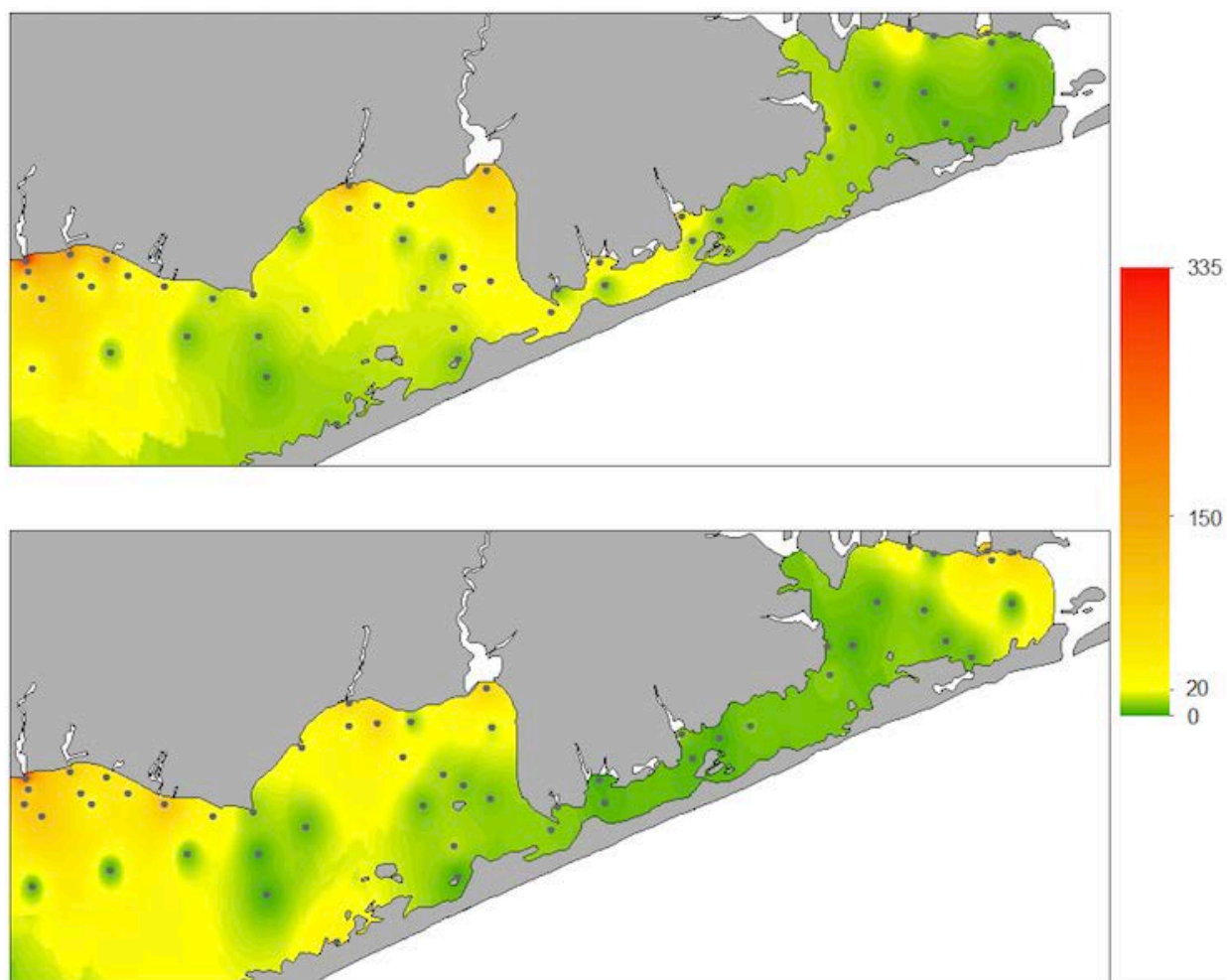


Figure 12. Mean fecal coliform levels before (top) (2010 - October 2012) and after (bottom) (February 2013 – 2014) the formation of the new breach. Interpolation between points generated through inverse distance weighting. Levels declined throughout Narrow Bay and portions of Bellport Bay in close proximity to the new breach.

Discussion and Conclusions

Although Hurricane Sandy caused major disruption in wastewater handling procedures on Long Island, leading to spikes in indicator bacteria and shellfish harvest area closures across much of the south shore of Long Island, the formation of the new breach as a result of the storm may have improved water quality in eastern Great South Bay, and particularly in Narrow Bay. Potential impacts of the new breach on fecal coliform levels were seen across all regions examined, but primarily at sites either uncertified or seasonally certified for shellfish harvest. While uncertified and seasonally certified sites in Region 5 (Nicoll Bay) showed a consistent decline in indicator bacteria levels following the formation of the new breach, decreases at sites in Region 6 (Patchogue Bay) and 7 (Bellport Bay) were limited to 2013. Despite any declines, fecal coliform levels in each region remained above 49 MPN/100 ml. Certified shellfish harvest sites in Region 7 (Bellport Bay) also displayed a similar short term decline in fecal coliform levels, though certified sites in Region 5 (Nicoll Bay) and 6 (Patchogue Bay) showed little evidence of any changes in indicator bacteria levels following the formation of the new breach. Little change in coliform levels was seen in the certified areas of western Moriches Bay, though peak fecal coliform levels in uncertified areas increased following the breach.

A large decline in fecal coliform levels following the formation of the new breach was observed in Narrow Bay, and unlike other regions this decline was sufficient to reduce fecal coliform levels below 49 MPN/100 ml, a benchmark relevant to NYSDEC shellfish harvest standards. The decline in Narrow Bay was also the only such trend in eastern Great South Bay that persisted beyond 2013. This was a significant finding, as the majority of Narrow Bay is currently either uncertified or only seasonally certified for shellfish harvest (Fig 13). As the contaminated areas of Narrow Bay are located in the closest proximity to the new breach of all coastal bays examined, this provides the strongest evidence that the new breach may have influenced indicator bacteria in local waters. It is notable that on August 12th 2014, Long Island set a record for the largest 24-hour rain event in the history of New York State. Rainfall totals were highly variable, but the region near Narrow Bay received more than 13 inches of rain and yet fecal coliform bacteria levels were unchanged (Fig 8). With enhanced circulation from the breach, it appears that this region is more resistant to contamination by pathogenic bacteria.

Collectively, these results show that while the new breach has affected indicator bacteria in eastern Great South Bay, persistent changes may be temporally and spatially limited. In some regions of Patchogue Bay, Bellport Bay, and Western Moriches Bay, levels of fecal coliform bacteria decreased significantly in 2013 but then increased to levels similar to before the formation of the breach. The most consistent declines in fecal coliform levels are seen in areas in closest proximity to the breach, namely the southeast portion of Bellport Bay and Narrow Bay. This is likely due to increased flushing in the region brought by open access to the ocean, reflected by simultaneous increases in salinity in these areas. This effect may be diminished in areas located further from the breach. Increases in peak levels in 2014 in some areas may also be due to the large August 2014 rainfall event. For example, with the exception of the August 2014 sampling event, Bellport Bay had lower fecal coliform bacteria levels than it had prior to the formation of the new breach.

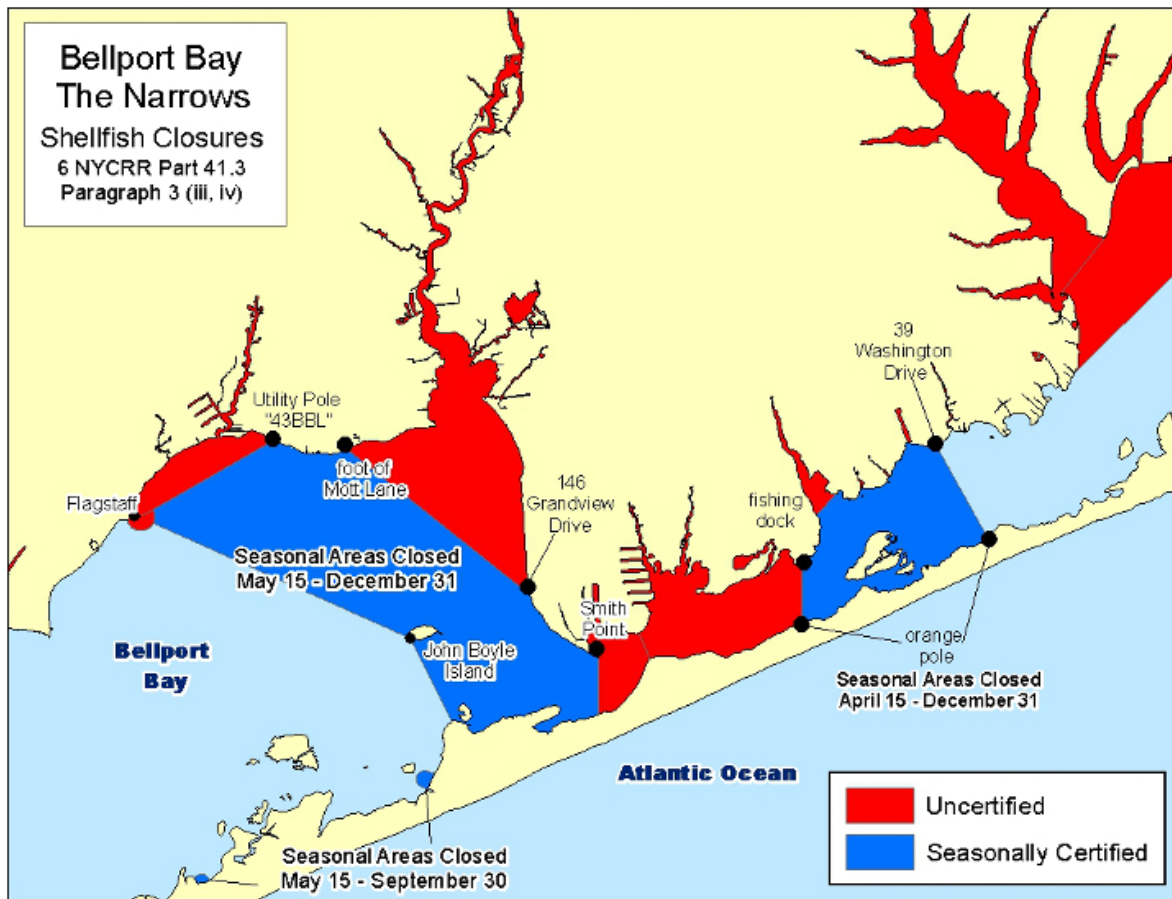


Figure 13. NYSDEC designation of shellfish beds in Narrow Bay as of 2015. Our analyses indicate that the new breach has reduced indicator bacteria levels in Narrow Bay to an extent that may warrant shellfish harvest certification in coming years pending additional data collection. Closed regions within Bellport Bay may also be reconsidered.

The finding that enhanced flushing by the new inlet has depressed levels of fecal coliform bacteria is consistent with some but not all prior studies of fecal indicator bacteria. On the one hand, sediments are known to be a reservoir of indicator bacteria (Lee et al., 2006; Fries et al., 2008) and the now strong tidal exchange and breaking waves are certainly more likely to re-suspend sediments in Bellport Bay. This could partly explain the slight elevation in fecal coliform bacteria in regions east and west in the new beach where re-suspended could settle (Fig 12). Alternatively, the ultimate source of fecal indicator bacteria in Great South Bay are more likely to be from animals and septic tanks from the mainland of Long Island (Sanders et al., 2005) and thus the levels of indicator bacteria in the vicinity of the new breach may be low. Moreover, ocean water in the region (NYSDEC long term data) and other locales (Sanders et al., 2005) have been found to have few if any fecal indicator bacteria, and hence the action of new breach bringing more ocean water into Bellport Bay is likely to dilute the indigenous population of bacteria.

There exists a host of additional questions that could be addressed regarding the effects of the new breach on indicator and pathogenic bacteria in Great South Bay. Given mild increases in indicator bacteria is regions east and west of the new breach (Fig 12), it is important to determine if indicator

bacteria are simply being redistributed in the Great South Bay instead of flushing out of the Great South Bay. Monitoring of indicator bacteria should continue to determine not only if Narrows Bay be re-evaluated for shellfish harvest due to decreases in indicator bacterial levels, but also other regions should be re-evaluated as well due to increased levels. In addition, the dynamics of other indicator and actual pathogen bacteria in Great South bay should be evaluated. Recently, accumulation of pathogenic strains of the bacteria *Vibrio parahaemolyticus* in shellfish have caused illnesses in NY estuaries (DePaola et al., 2000). The distribution of this microbe in Great South Bay is unknown, but should be evaluated in the vicinity of the new beach.

Based on these analyses, the formation of the new breach and its introduction of oceanic water into Narrow Bay have reduced fecal coliform levels; a continuation of this trend may warrant an eventual reevaluation by NYSDEC of the shellfish harvest certification status of this area. The standard practice of closing naturally formed breaches following storm events should also be reconsidered, as the new breach shows evidence of remediating some of the most impacted coastal waters on the south shore of Long Island. The full extent of any benefits, including any economic or social aspects from potential increased shellfish harvest, will likely not be realized for several years, and will serve to demonstrate the need to fully evaluate any changes in physical properties of coastal ecosystems prior to response efforts.

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