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Assessing the Impact of a New Inlet Created by 2012 Hurricane Sandy on the Intensity of Algae Blooms in Bellport Bay NY

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Abstract

Harmful algae blooms (HABs) are a growing ecosystem health issue in environments worldwide, driven by excess nitrogen runoff (Eutrophication) alongside high summer temperatures. HABs strip oxygen from the environment and create toxic environments that impact other primary producers, fish, birds, mammals, reptiles, and any other organisms that enter an affected body of water. The purpose of this study is to analyze the impact of a new inlet, created by Hurricane Sandy in Long Island's Bellport Bay, on the concentration of algae blooms during peak blooming periods (Jul-Aug) to inform ecosystem-based management. Google Earth Engine Code Editor and 2008-2017 Landsat 5-8 imagery correlated to the study area were used for imagery and data analysis. The colored infrared (CIR) before & after images of the study area clearly show the new inlet formation and shoal structure in Bellport Bay. Normalized Difference Vegetation Index (NDVI) imagery analysis found a significant decrease in algae bloom concentration, in close proximity to the new inlet formations. Additionally, NDVI imagery analysis found that algae concentration decreased across nearly the entire Moriches and Shinnecock bays, partly due to their pre-existing inlets. This shift is attributed to the differences in local watershed characteristics and waste management strategies across the bays, over the time period of analysis. This study concludes that the formation of new inlets can be beneficial in lowering algae concentrations in appropriate coastal areas afflicted by HABs. However, the primary focus for reducing HABs in all environments must be reductions in anthropogenic nitrogen loading, driven by ineffective land and water management practices overtime.

Keywords

Harmful Algae Blooms (HABs), Eutrophication, Normalized Difference Vegetation Index (NDVI), ecosystem based management, natural resource management

Disciplines

Environmental Indicators and Impact Assessment | Environmental Sciences | Environmental Studies | Water Resource Management

Comments

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Abstract

Harmful algae blooms (HABs) are a growing ecosystem health issue in environments worldwide, driven by excess nitrogen runoff (Eutrophication) alongside high summer temperatures. HABs strip oxygen from the environment and create toxic environments that impact other primary producers, fish, birds, mammals, reptiles, and any other organisms that enter an affected body of water. The purpose of this study is to analyze the impact of a new inlet, created by Hurricane Sandy in Long Island's Bellport Bay, on the concentration of algae blooms during peak blooming periods (Jul-Aug) to inform ecosystem-based management. Google Earth Engine Code Editor and 2008-2017 Landsat 5-8 imagery correlated to the study area were used for imagery and data analysis. The colored infrared (CIR) before & after images of the study area clearly show the new inlet formation and shoal structure in Bellport Bay. Normalized Difference Vegetation Index (NDVI) imagery analysis found a significant decrease in algae bloom concentration, in close proximity to the new inlet formations. Additionally, NDVI imagery analysis found that algae concentration decreased across nearly the entire Moriches and Shinnecock bays, partly due to their pre-existing inlets. This shift is attributed to the differences in local watershed characteristics and waste management strategies across the bays, over the time period of analysis. This study concludes that the formation of new inlets can be beneficial in lowering algae concentrations in appropriate coastal areas afflicted by HABs. However, the primary focus for reducing HABs in all environments must be reductions in anthropogenic nitrogen loading, driven by ineffective land and water management practices overtime.

Introduction

Algal blooms in the bays and waters surrounding Long Island, NY have been a major focus of concern and conservation since 1985. The reason being the massive death of fish and invertebrates in the ecosystem driven by eutrophication (nitrogen loading) that results in extremely large Brown Tide (*Aureococcus anophagefferens*) (Hattenrath-Lehmann and Gobler 2018). Harmful Algal Blooms (HABs) create a hypoxic environment that strips nearly all available oxygen from the water and killing organisms within the bloom and a toxic environment that impact the health of all organisms that interact with an affected area (Gobler et al. 2019). These HABs typically occur in the summer as a result of the optimal conditions for growth created by warmer summer temperatures (Hattenrath-Lehmann and Gobler 2018). In addition, the role of nitrogen pollution from anthropogenic sources such as fertilizers and waste plays in nitrogen loading the bays to fuel HABs cannot be understated (Lloyd 2014; Young and Gobler 2016). As shown in a 2012 study performed on the Shinnecock Bay ecosystem on a blooming species of algae known as Rust Tide (*Cochlodinium polykrikoides*) that displayed increases in growth with increases in nitrogen (Gobler et al. 2012). The algal blooms severity intensified until the year 2012, after the intensity of blooms began to decrease to more manageable levels in some areas (Hattenrath-Lehmann and Gobler 2018).

This shift corresponds with the creation of a new inlet in the Bellport Bay (eastern Great South Bay) from Hurricane Sandy in November of 2012. The creation of this new inlet could allow for a dilution of nutrients (like nitrogen) in the bays due to the influx of less nutrient dense ocean water. However, in a news article about the formation of the new inlet claims that it has potentially worsened blooms in the Great South Bay, despite the impact of the influx of ocean water (Gralla 2018). The primary purpose of this study is to assess the significance of the creation of the new inlet in the Bellport Bay, in terms of the role it plays in reducing the severity of HABs in the context of the study area. The primary focus of this research is based upon the following research questions: What is the overall impact of the creation of the new inlet on algal blooms in the Bellport, Shinnecock, and Moriches Bays? Why do certain areas experience greater or different change than others? How can problem areas be better managed to reduce algal bloom severity and environmental impact?

Methods

The study area encompasses three small bays on the eastern south shore of Long Island, coastal mainland Long Island and the Long Island’s barrier islands that create its southern bays (Figure 1). The change analysis for this study area was performed using an Earth Engine Code

Editor using Landsat 5 & 8 Imagery (Table 1). To begin representing the change, an annual time series analysis was performed to display the change in algae concentration over the years 2008-2017 (only for the months of July and August) using two points that best demonstrate the change (Figure 1). The months of July and August were used because these months have historically featured significant HABs (Hattenrath-Lehmann and Gobler 2018). For this study, a Normalized Difference Vegetation Index (NDVI) is used to represent algae concentration. One of the points chosen for this time series featured an area expected to experience little to no decrease in Normalized Difference Vegetation Index (NDVI), while the other point chosen featured an area expected to experience a significant decrease in NDVI or algae concentration. The equation used to detect the presence of algae was NDVI for the entirety of the study, (NIR – RED) / (NIR + RED), with values that range from -1 to 1 (Boucher et al. 2018).

In addition, an unsupervised classification was performed to represent the changes in algae concentration that occurred before and after Hurricane Sandy in 2012. The unsupervised classification featured images from five seasonal periods, both before (07/01/2008 - 09/01/2012) and after (07/01/2013 - 09/01/2017) the creation of the new inlet in 2012. There was a total of 28 images in the before and 39 in the after, the difference occurred due to the removal Landsat 7 imagery because of the data gaps created from the satellite's malfunctioning scanline corrector. The classification also excluded all images with over 25 percent cloud coverage to ensure minimal cloud masking in the images used. The classification was created using 20 spectral classes that were broken down into three information classes (Significant Decrease in Algae Activity, No Significant Decrease in Algae Activity**,** Land (other)). Before creating the classification, Color-infrared (CIR) images aided in demonstrating the creation of the inlet that occurred between the before and after period of the classification. In addition, an image was created to represent the difference in NDVI (dNDVI) of the study area from the before versus after period to show the change in algae concentration. All three of these images, along with dNDVI values were used to classify the spectral classes into the information classes manually. The no significant change class featured dNDVI values of water of 0.1 or less, while the significant change class featured dNDVI values of 0.1 or greater. Once the classification was created, the three classes were analyzed to determine their individual total areas and percentages of the total study area.

To analyze the accuracy of the classification, a random stratified sample was created using 25 points within each class (75 points total). The points created by the sample were then compared to the dNDVI image as well as the before and after CIR images. Additionally, a confusion matrix was created to calculate the user and producer's accuracy for the three classes, as well as the overall accuracy of the classification.

Results

The time series analysis graph (Figure 2) shows the change in NDVI overtime for July and August at the two points shown in Figure 1. The point representing an area of the bay expected to experience no significant change in algae concentration, shows consistently high NDVI values (0.2 to 0.4) overtime. There is no clear change that occurs before or after the creation of the inlet in the summer of 2012 at this point. The point representing an area of the bay that expected to experience significant change in algae concentration shows considerably lower NDVI values in comparison (-0.1 to -0.6). There is a clear decrease in NDVI that occurs after the creation of the inlet in the summer of 2012.

The creation of the new inlet in Bellport Bay is represented by the before and after CIR Landsat images (Figures 3 & 4). In the before image (Figure 3), there is no clear evidence in the Bellport Bay of an inlet when compared to the Moriches and Shinnecock Bay which feature inlets in the before and after images. In the after image (Figure 4), there is clear evidence of a new inlet in Bellport Bay based upon the shift from land to water around the barrier island and the similar physical characteristics of the pre-existing inlets in the area.

The classified image in Figure 5 displays that the majority of the area of the bays are experienced a decrease in dNDVI values that was greater than 0.1, with a less significant portion of the area represented by areas that experienced minimal decrease in dNDVI values (dNDVI = 0 to 0.1). The image of dNDVI (Figure 6) of the study area shows that the area of the Bellport Bay that experienced the largest decrease in the entire study area, located directly in front of the newly formed inlet. The rest of the bay mostly showed little to no decrease in algae concentration (NDVI value). Moriches Bay experienced a significant decrease in algae concentration over this time period; however, small areas that connect Bellport and Moriches bay experienced little to no decrease in algae concentration. Shinnecock Bay experienced a significant decrease in algae concentration over this time period, with very small areas of little to no decrease in algae concentration.

The overall area accuracy of the classification was 90.7% with seven errors of commission for the land class, six errors of omission for the No Significant Decrease in Algae Activity class and one error of omission Significant Decrease in Algae Activity (Table 2). The total area of the Significant Decrease in Algae Activity class is 72.5 km with a percent of total area of the study area of 27.5% (Table 2). The total area of the Significant Decrease in Algae Activity class is 29.1 km with a percent of total area of the study area of 11.1% (Table 3).

Discussion

The formation of the inlet is the change that sparks the change in NDVI (or Algal Activity) in the study area and can be most clearly in the before and after CIR images. When observing the before image, the inlets of the Moriches and Shinnecock Bays are clearly visible due to their shoals (bayside sand accumulation at inlet), with no visible inlet or shoal in the Bellport Bay. However, in the after image the Bellport Bay shows a clear inlet as well as similar characteristics to the inlets found in the two neighboring bays. These shoals have a large positive impact, as they provide habitat for eelgrass (*Zostera marina*), blue mussel (Mytilus edulis), hard clam (*Mercenaria mercenaria*), eastern oyster (*Crassostrea virginica*), and a variety of other local primary producers and consumers species. This new inlet has the potential to create changes in the water quality of the bay and thus the severity of algal blooms (Gobler et al. 2019). However, the effectiveness of the new inlet in reducing the overall severity of algae blooms is still in question because of their relationship to coastal nitrogen runoff. The significant changes in the Shinnecock and Moriches Bays over this same time period can be attributed to shifts in local policy on waste management. An additional factor is the land use and land area of the watershed that runs off into the southern bays, where the Shinnecock and Moriches bays have more favorable waste and watershed management circumstances. These factors alongside the already present inlets and local restoration efforts from Cornell Cooperative Extension, The Moriches Bay Project, Back to the Bays and many other local partners and volunteers.

The times series graph highlights the key problem of anthropogenic nitrogen pollution's contribution to eutrophication and the limitations of the impacts of new inlets. The line that represents the most significant area of decrease in algae activity (directly in front of the new inlet) shows an area of the Bellport Bay that did not suffer from severe algal blooms before the creation of the inlet. This means that an area that already had manageable algal blooms, became an even more stable environment. This is by no means a negative, the habitat created around the new inlet has shown to be extremely beneficial to the overall health of bivalve populations (Gobler et al. 2019). This concept becomes extremely clear when comparing the NDVI values of the two different lines. The other line represents an area in the same bay that experience almost no change as a result of the new inlet and its NDVI indicates that there are HABs occurring in that area of the Bellport Bay over a 10-year period. This means that an area that was already in dire need of a drastic decrease in algal activity, experienced the least amount of decrease from the formation of the new inlet. This means that the formation of the new inlet is only a localized answer to reducing algal activity and that shifts in land, water and nitrogen management must occur to reduce HABs.

It is also important to note that in the classified image of dNDVI and dNDVI image (Figures 5 & 6), the majority of areas that did not experience significant decrease in NDVI occur along the bayside beaches of mainland Long Island. One key limitation of the classification was the inability of Landsat imagery to differentiate between land and water pixels along coastlines. An easy fix to improve this issue would be to use imagery with better spatial resolution than Landsat, however, the accuracy of classification did not severely suffer. These areas are most prone to algal blooms as a result of the deposition of anthropogenic nitrogen pollution through the watershed or run-off (Lloyd 2014). Once again, this highlights that the formation of a new inlet should not be viewed as a blanket solution to algal bloom issues. Instead, this suggests that the key issue that must be addressed in order to reduce HABs is through reducing anthropogenic nitrogen loading of the bays.

The reason that reducing the concentration of nitrogen is vital is because excess nitrogen can be a key driver of common blooming algae species (Gobler et al. 2012). In addition, a study on two common blooming species of algae in the Shinnecock Bay showed that increases in dissolved carbon dioxide in water (resulting from increases in anthropogenic carbon emissions) promoted significant increases in algal activity (Young and Gobler 2016). Although not directly related, this shows further evidence of how anthropogenic pollution is contributing to the intensification of HABs. The study also notes that these increases were also contributed by subsequent increases in Nitrogen, but not in all cases (Young and Gobler 2016). Based upon the combination of this research and past research, the most crucial mitigation effort to minimizing future HABs is through the reduction of human's nitrogenous waste (Hattenrath-Lehmann and Gobler 2018).

Another potential pathway forward to better manage HABs in the future is through the development of a precise and accurate HAB alert system. The alert system being referenced is known as the CyanoTracker, which combined cloud-sourced citizen science data in combination with onsite CyanoSensors and satellite imagery (Mishra et al. 2020). Through the implementation of this system within the study area, understanding the contributing factors to algal blooms will become more effective. By tracking a blooming event in more detail, more specific causes and characteristics will arise to help identify the best management strategy to prevent future blooms.

Overall, the formation of the new inlet by Hurricane Sandy in 2012 created a localized significant decrease in algal bloom severity in close proximity to the inlet as a result of the increased tidal exchange with the ocean. However, the shallow coastal areas closest to mainland Long Island subject to the most severe algal blooms experience little to no decrease because of ineffective sewage & waste management strategies. Additionally, demonstrating the limitations of the increased water flow provided by the inlet, on eutrophication. With this in mind, the importance of increased water flow cannot be ignored, however, it does not negate excessive nitrogen loading of the bays that cause the HABs. To address these issues, blooming events must be tracked with more precision and the importance of minimizing the nitrogen loading of the bays through effective land, water, and waste management strategies. Additionally, this study showcases the importance of an ecosystems-based management approach for biotic and abiotic resources.

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Figures and Tables

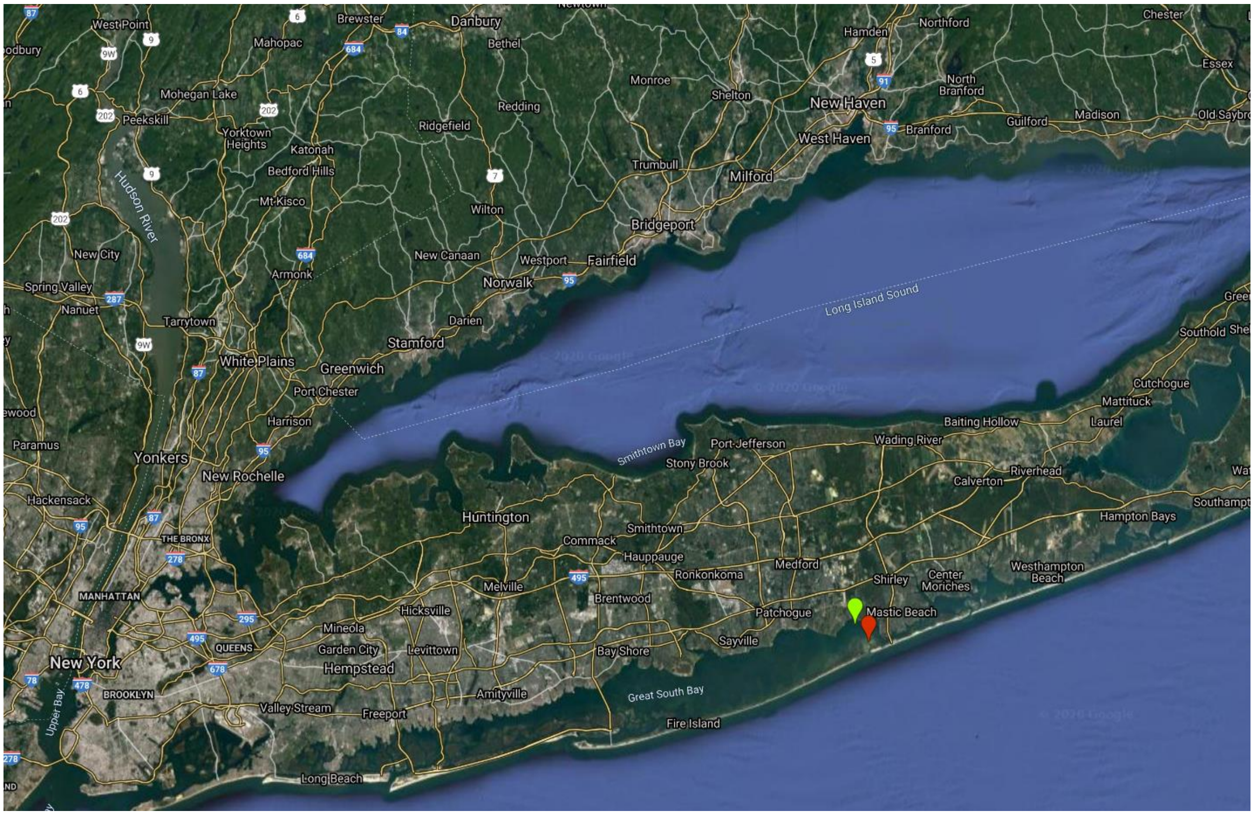


Figure 1. This map provides perspective on the general location of the study area (marked by green and red points in this image) in reference to New York City (bottom left corner). The red marker represents a section of the Bellport Bay (eastern Great South Bay), in close proximity to the inlet created by Hurricane Sandy in 2012. The green marker also represents a point in the Bellport Bay in an area that showed little to no change.

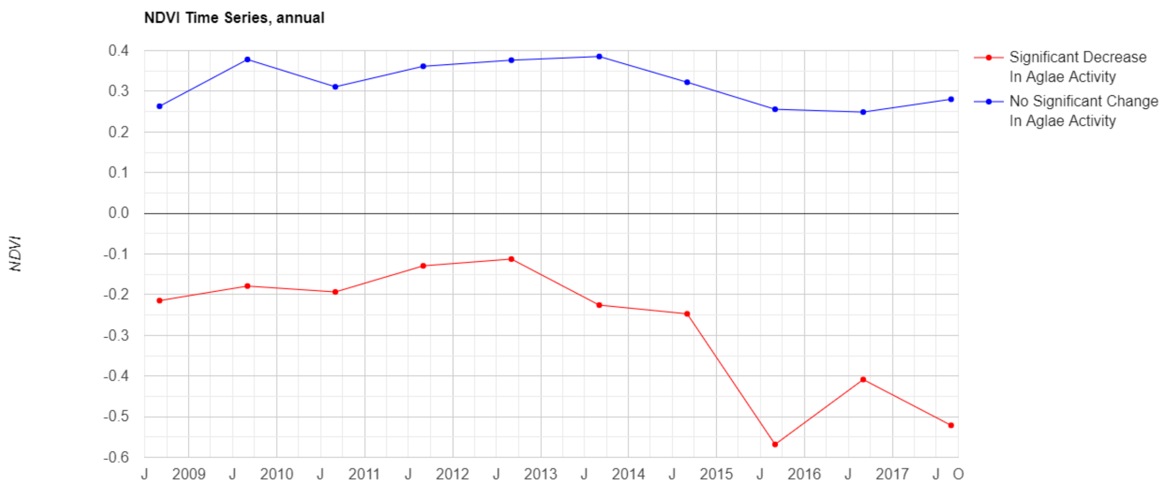


Figure 2. This graph displays an annual time series analysis on NDVI to observe a 10-year period (2008-2017) During only the months of July and August, using the two points referenced in Figure 1. The creation of the new inlet occurred in the fall of 2012, showed varying decreases in NDVI across the Bellport Bay as well as in the Shinnecock and Moriches Bays.

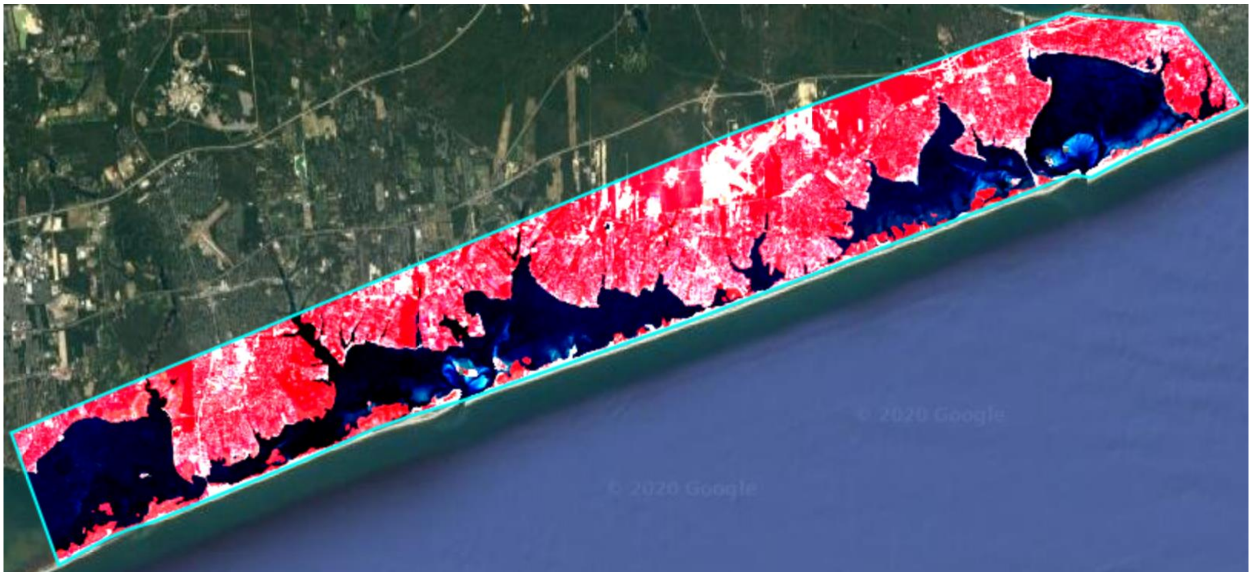


Figure 3. This is a color infrared (CIR) composite image from 28 Landsat images displaying the study area before the creation of the new inlet (images from July 2008 to August 2012). Prior to the creation of the inlet, the Bellport Bay (left of study area) lacks the flashes of white/blue seen adjacent to the inlets of the Moriches(middle) and Shinnecock Bays (right).

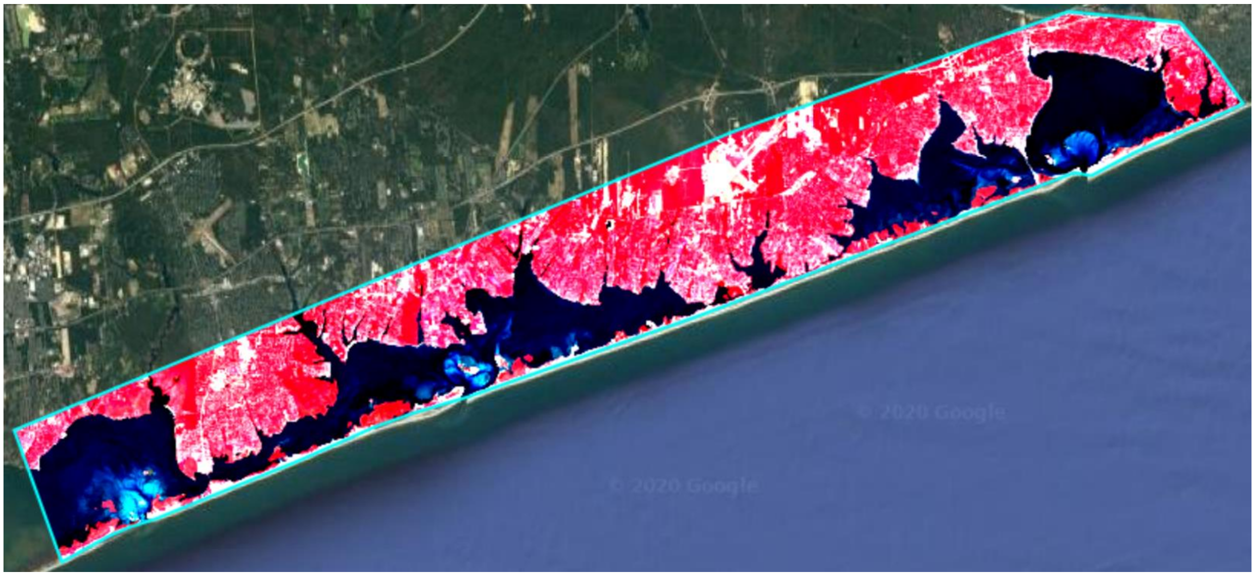
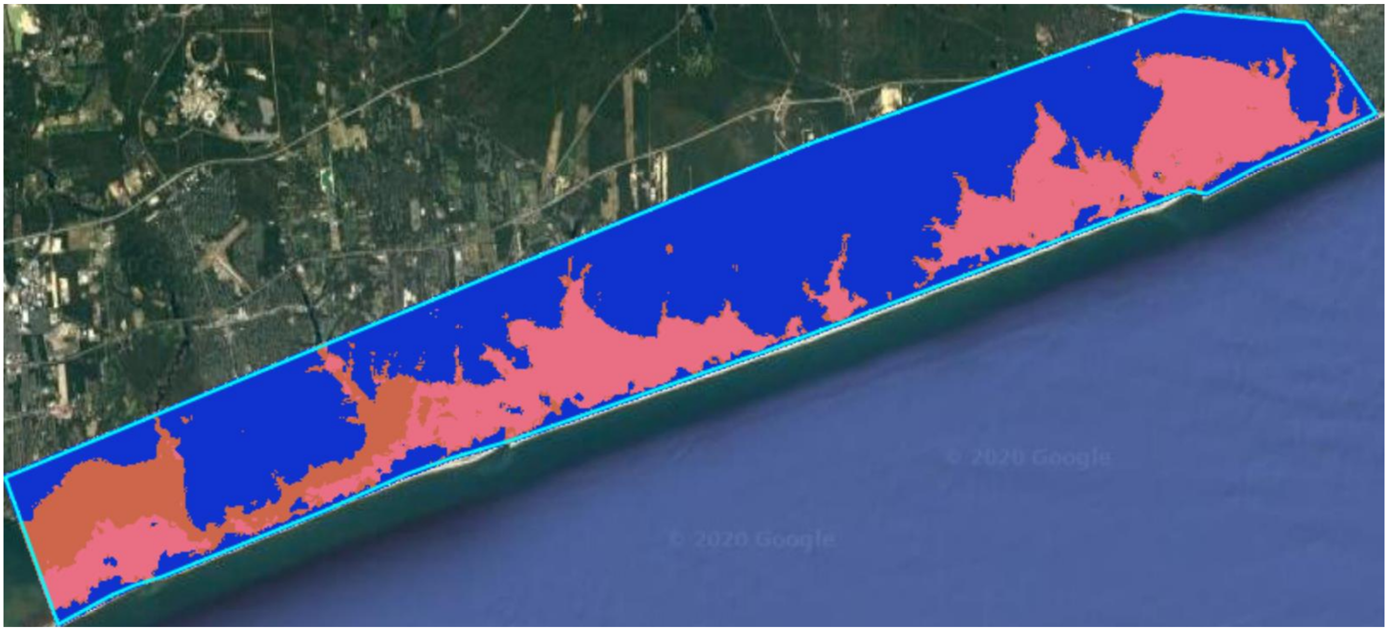


Figure 4. This is a color infrared (CIR) composite image from 39 Landsat images displaying the study area after the creation of the new inlet (bottom left corner) by Hurricane Sandy in November of 2012 (images from July 2013 to August 2018). After the creation of the inlet, the Bellport Bay now has the flashes of white/blue at the entrance of the bay.



Legend	Class
	Significant Decrease in Algae Activity
	No Significant Decrease in Algae Activity
	Land (other)

Figure 5. This image shows a classified map of the change in NDVI or dNDVI that occurred in the study areas of the three bays (Bellport, Moriches, Shinnecock) before and after the creation of the new inlet. The areas of red represent areas of the water that experienced little to no significant decrease in algal activity after the creation of the new inlet by Hurricane Sandy. The areas of pink represent areas water that experienced a significant decrease in algae activity after the creation of the new inlet by Hurricane Sandy. The areas of blue represent any kind of land mass in the study area.

Figure 6. This Landsat image represents the dNDVI of the study area using a monochromatic coloration (black and white). The darker the color of the imagery the larger the change in NDVI that occurred after the creation of the new inlet in 2012 by Hurricane Sandy. The lighter the color of the imagery the smaller the change in NDVI that occurred after the creation of new inlet.

Table 1. Data Sources used to complete this study.

Name	Who Created	Time valid for	Description
Landsat 5 & 8 (under the Landsat Data Continuity Mission)	NASA and USGS	2008-2017	Imagery of southern bays of Long Island to access changes in algal blooms before and after Hurricane Sandy in 2012.

Table 2. Confusion Matrix using a random stratified sample of the classification of change imagery.

		Reference	Source			
		Significant Decrease in Algae Activity	No Significant Decrease in Algae Activity	Land	Total	User's Accuracy
Classified	Significant Decrease in Algae Activity	25			25	1.00
Map	No Significant Decrease in Algae Activity		25		25	1.00
	Land	1	6	18	25	0.720
	Total	26	31	18	75	
	Producer's Accuracy	.962	.806	1.00		Overall = 0.907

Table 3. Table of Classification Results - Overall Area and Percentage of Classification of Change Map

Classification Type	Area (km^2)	Percent (%)
Significant Decrease in Algae Activity	72.5 km^2	27.5 %
No Significant Decrease in Algae Activity	29.1 km^2	11.1 %
Land	162 km^2	61.4 %